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VOLCANOES OF THE OTAHUHU-MANUREWA DISTRICT, AUCKLAND

By E. J. SEARLE, Department of Geology, University of Auckland

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Abstract

The area described is part of a Pliocene-Pleistocene basin of sedimentation that is bordered north and south by terrains of Waitemata Formation. Three groups of Recent or Sub-Recent Volcanoes are described. Those close to the margins of the basin were dominantly effusive in type; those more remote were wholly phreatic. Evidence is presented that the vents are distributed in a north-trending zone which is shown to be in conformity with a pattern of broader significance in the Auckland volcanic field.

INTRODUCTION

The portion of the Auckland volcanic field considered in this article lies to the south of the isthmus and east of the Mangere-Ihumatao district, the volcanoes of which were the object of an earlier contribution of the writer (Searle, 1959). The area described (Fig. 1) is bounded on the east by Tamaki inlet and thence by a line running south-east to Manurewa.

Together with the Mangere-Ihumatao area it occupies part of a down faulted region constituted of sandstones, mudstone and peat beds of Pliocene-Pleistocene age (Kaawa Formation of Schofield, 1958: Lignite Formation of Hochstetter, 1864), resting on an eroded and uneven surface of Waitemata strata. The younger rocks are contained in a basin margined to the south and south-east by emergent, higher-standing areas built of Waitemata rocks. Over this area a number of Late Pleistocene-Recent volcanoes have spread a mantle of volcanic products.

VOLCANOES OF THE DISTRICT

The main volcanoes of the district have been listed by Hochstetter (1864), those of the southern groups were described briefly by Firth (1930), and Wong (1946) examined those in the north of the area. In this account

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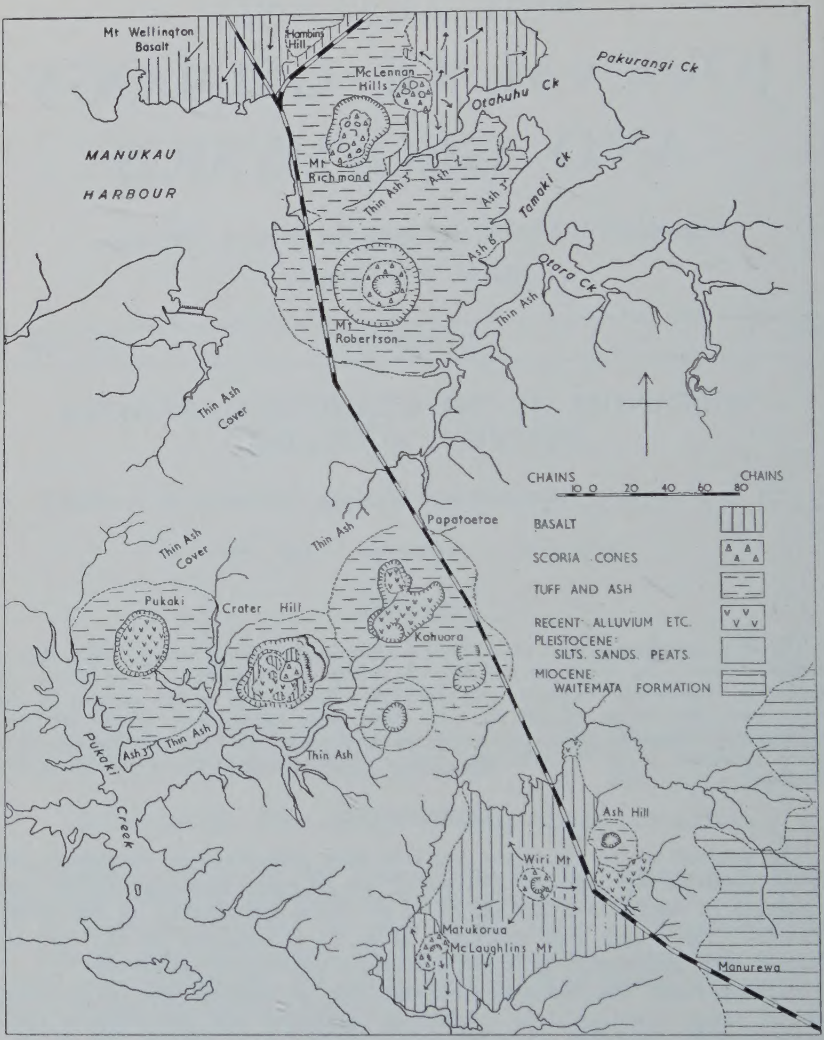

FIG. 1—Geological sketch map of the Otahuhu-Manurewa district of the Auckland volcanic field.

they will be considered in three groups: those of Wiri near the southern border; the Otahuhu volcanoes to the north; and those of the central and deeper part of the basin near Papatoetoe.

The Wiri Group

The Wiri group of volcanoes consists of three eruptive centres disposed along a line bearing 050°. McLoughlins Hill (Matokurua), the most southerly, and Wiri Mountain (Mangere) are both scoria cones surrounded by an extensive lava field. "Ash Hill" to the north appears to have been the site of a minor phreatic eruption that built a tuff cone with a small explosive crater.

Wiri Mountain has been built up by vigorous firefountaining from a number of vents which opened up over a small area, as the focus of eruption shifted from point to point, and from which there was a prodigal outflow of lava. Extensive quarrying for railway ballast has so reduced the cone, formerly approximately 300 ft high, that it is now very difficult to recognise the original form. Apparently it was a rather squat mound of scoria with a single summit crater and stood on a broad base of lava. Sections through the structure show that it was made largely of black, chunky scoria, together with spatter products, reinforced by many thin flows of small extent such as would be likely to form as the result of ponderous splashing of highly fluid lava. The sites of active vents are indicated by several plug-like masses of lava-welded scoria and by bodies of scoriaceous basalt. The beds of scoria are at times cut by small irregular dykes, occasionally cavernous in the centre and, in this manner, are reminiscent of the hollow dyke at Mt. Wellington described by Bartrum and Searle (1948); some of them are associated with small flows interbedded with the layers of scoria and, in some instances extend out from the foot of the cone to build up a massive lava platform above the level of the main lava field on which the system stands. At least eight such thin flows are shown in a railway cutting into the main quarry area, through the platform and lower part of the cone. Some of these flows are scarcely more than a foot or two in thickness, whilst others are as much as 10–12 ft thick. They are separated one from another by markedly scoriaceous surfaces and in places by several feet of loosely packed scoriae.

The general impression gained from a study of the structure of the cone is that early activity of the volcano produced a considerable quantity of lava which flooded the low-lying area whilst spatter activity formed a small cone near the main vents. In this way a lava field was formed early in the history of the centre and flows were piled up to a thickness of approximately 60 ft. Later activity declined and thinner flows of more limited extent were produced. In a basalt quarry south-east of the mountain, for example, a flow 4 ft thick rests on a lower more massive one that is approximately 25 ft thick, the two being separated by 3–4 ft of coarse scoriaceous debris. The closing phases were marked by more explosive activity with small firefountains that built up the central edifice and gave rise to minor flows that spread at the foot of the cone and formed a massive pedestal.

Firth (1930) noted the markedly meandering course of Puhinui stream after it leaves the sandstone terrain to skirt the edge of the lava flows in a wide, clearly-defined flood plain, and suggested that the stream was established in this course before the lava was emplaced. This does not seem at all likely for drilling on the northern portion of the lava field indicates a buried topography much more deeply incised than that now developed on the surface of nearby sedimentary rocks, whilst the deflection of the stream where it makes contact with the lava is clearly indicative of diversion.

In the New Zealand Railways Basalt Reserve, north of Wiri Mountain, exploratory drilling has shown that the basalts rest upon a surface of clay or mud, that descends to approximately sea level on the side of the reserve adjoining the mountain. The surface of the sedimentary rocks beneath the flows is thus cut down to more than 50 ft below the level of the surface of the sedimentary rocks subjacent to the lavas. From sections drawn from the logs of the bores it may be inferred that in pre-volcanic times an estuary of the ancestral Puhinui stream was located in the area that is now occupied by the volcanic formations. It is less difficult to imagine that the stream has been displaced from its earlier course, and that it has become entrenched along the margin of the flows, than to suppose that the spread of lava was arrested on reaching such a small stream valley. Along the southern boundary of the lava field another small stream has similarly become entrenched with a steep wall of basalt forming its right bank.

Smaller streams draining into the ancient Puhinui estuary from the slopes of Waitemata formation rocks east of Wiri mountain have been dammed by the lava field. The lower parts of their valleys have been alluviated and now form swampy flats behind the lava barrier.

Of the three volcanoes in the group, Wiri Mountain is certainly older than McLoughlins Hill, since the lavas of the former pass under the volcanic products of the latter. Its age relationship to the explosive centre of "Ash Hill" is not clearly shown for swamp deposits now mask the critical area between the two. It would seem likely, however, that explosive eruptions at "Ash Hill" preceded effusion of lava from the Wiri volcano as the surface of the lava field is notably clean of ash which might otherwise be expected to veneer its surface. It must be admitted that the eruptions at the "Ash Hill" centre were not on a large scale. The explosive crater is small and was formed by eruptions from a site on a spur of Waitemata rocks that emerged through, or was, at most, lightly covered by the younger sedimentary deposits. It is probable that the elevation of the feature does not arise solely from the deposit of tuff but is due in some measure to a rise on the surface of the Waitemata strata. Nevertheless eruption would seem to have been vigorous enough to have plastered the surface of the Wiri flow with tuff had the lava already been in place before the "Ash Hill" eruptions occurred. It may be inferred, therefore, that activity in this group of volcanoes commenced at the north-eastern end of the group and shifted towards the south-west down a clearly defined line. A comparable shifting of activity along a line of centres was demonstrated for the volcanoes in the Ihumatao chain by Searle (1959). No indication of the absolute dates of eruptions of the volcanoes in the Wiri group is yet available but specimens of wood collected from immediately beneath the lava of Wiri Mountain at present await radiocarbon dating. However, it may confidently be accepted that activity was comparatively recent. The condition of the surface of the lava field would indicate a time not far removed from that of activity at Mt Wellington which has been established as occurring approximately 9,000 years ago.

McLoughlins Hill (Fig. 2), approximately 200 ft high, is a scoria cone, crescentic in plan due to a breach on its southern face. This volcano has given rise to a rather limited lava field extending mainly over the area south of the cone. The topographic form and constitution of the small cone show that it has been built from material ejected from several short-lived vents. The fragmentals are coarse and clinkery and predominantly in

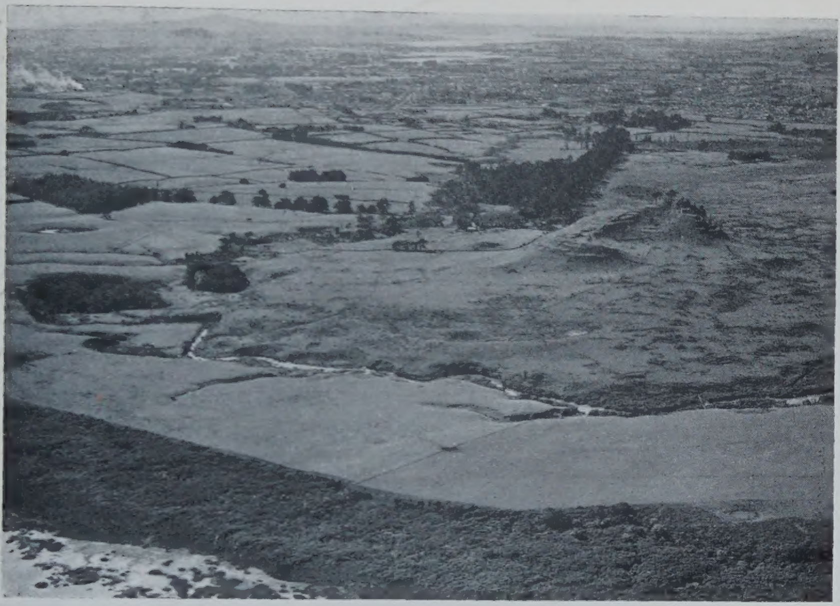

Photo: Whites Aviation Ltd.

FIG. 2—Air photograph of McLoughlins Hill showing scoria cone with breached crater. The lava field extends to Puhinui Creek (foreground). From the breach extends the main lava flow with ramparts bordering median collapse along the centre of the flow. Behind and to the right is a portion of Wiri Mountain lava field.

jumbled masses showing little grading or bedding. Numerous large bombs scattering the slopes bear witness to the vigour of explosions during the later phases of eruption. In the earlier stages some lava flows were formed, particularly towards the south-west, but the final form of both the cone and the small lava field has been dominated by events late in the eruptive history of the volcano when a major vent opened on the southern flank and blasted away a large part of the earlier structure – probably a double cone. Fire fountaining scattered scoria and irregular spatter fragments over the surviving portion of the cone behind the vent, and thus built up the crescentic rim. At the same time outflow of lava commenced to the south. Although a considerable lava stream was formed the supply of lava, at first abundant, soon slackened off. The result was that rapid outflow downstream drained the source upstream causing the median zone of the flow to founder. For this reason the flow today shows marked lateral ramps along its flanks and a concave surface hollowed along the centre line.

The Otahuhu Group

The volcanoes of this group, distributed over the narrow strip of land separating Tamaki Inlet (Waitemata Harbour) from Manukau Harbour, include Mt Robertson (now Sturges Park), Mt Richmond, and the McLennan Hills (Hamblin's Hill of Hochstetter, 1864). Some confusion has arisen from the transfer of the name of Hamblin's Hill to a nearby prominence and this has led to the latter being mapped (e.g. Fowlds, 1928) as a volcanic centre. This is not so, for the modern Hamblin's Hill is simply an erosional landform carved on high-standing Waitemata strata.

Mt Robertson at Otahuhu is a castle-and-moat structure with a low, broad tuff cone covering an area of half a square mile and possessing a shallow crater of approximately 40 acres. Sub-centrally situated inside the crater is a small scoria cone less than 50 ft high and with a base area of approximately 10 acres. The moat between the scoria mound and the tuff cone has been drained and developed as a sports area. The crater of the scoria cone, similarly, has been enlarged and levelled to provide an arena. The whole volcanic mass is seated on Pleistocene silts of the Kaawa Formation with an eroded surface at an elevation of approximately 20 ft above sea level.

Development of Sturges Park has interfered considerably with original profiles and outlines of the several units of the volcanic system but sufficient remains to show clearly the essential simplicity of the main eruptive events at the centre. Early eruptions were wholly phreatic or magmatophreatic and produced showers of lapilli and finely comminuted sedimentary debris, piled up thickly close to the volcano in what is now the main commercial centre of the town. Although spread widely the tuff thins rapidly as distance from the volcano increases and now forms a veneer only a few feet thick over the surrounding district. The pattern of eruption was one of successive relatively feeble explosions from a number of points of activity, in this manner forming a broad but shallow crater, and a tuff ring composed of well defined layers of fine debris, spread thickly to the south and east. Large blocks of cover rock and rather jumbled deposits that are typical of tuff cones such as that of Onepoto (North Shore) formed by more devastating eruptions are not encountered in the exposures of tuff on Mt Robertson examined by the writer.

This tuff-producing phase was followed by the rise of magma in one of the more centrally placed vents. The mode of eruption changed to fire-fountaining on a very small scale, the tiny scoria cone was built and activity ceased. Sections exposed in the flanks of the cones show that the materials produced in this final episode of eruption were slaggy, coarse-textured and ill-sorted. Bombs and irregular clots of slag are numerous and indicate that vigorous splashing of lava accompanied the production of scoria and lapilli. Both the symmetry of the cone and the disposition of the pyroclastic deposits show that activity was restricted to a single vent during the cone-building phase and the absence of blocks of scoriaceous or dense lava suggests that activity was continuous throughout the phase and was not interrupted by consolidation of lava in the vent between explosive outbursts. The picture is that of a turbulent well of fluid lava from which the encircling cone was built up by material splashed and showered out by escaping gases. The supply of lava and rate of extravasation were both inadequate to create a sufficient body of liquid lava to produce even a small lava flow.

Mt Richmond (Fig. 3), one mile to the north of Mt Robertston, and close to the margin of the Waitemata terrain, bordering the basin of Pleistocene sedimentation, is a much more complex structure. As at Mt Robertson the eruptive system is contained within a large tuff cone, here covering an area of more than a square mile. The explosion crater is elongated, a lobe in the

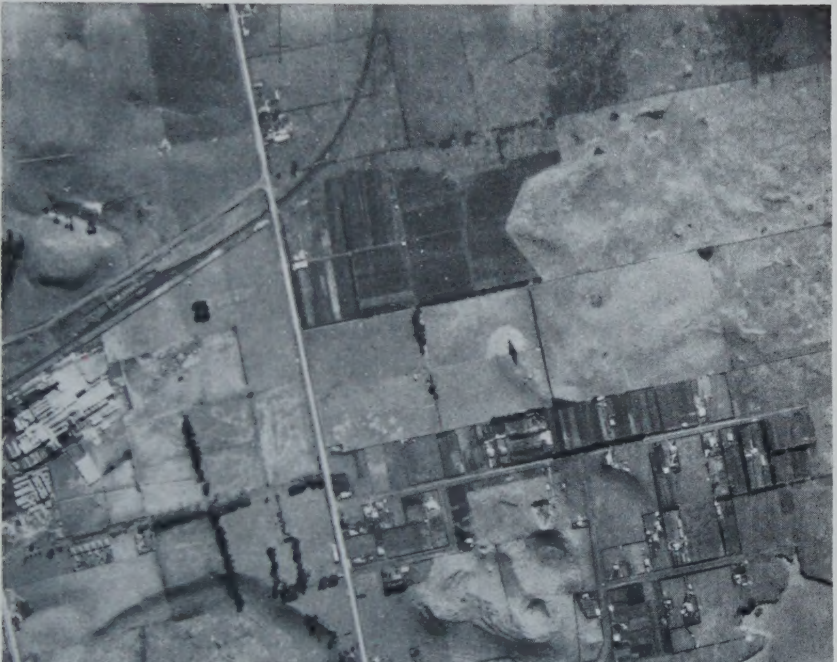

Photo: NZ. Aerial Mapping by courtesty of the Surveyor-General.

FIG. 3—Vertical air photograph of Mt Richmond (left) and McLennan Hills systems as they were in 1949. Top left, beyond the railway, Hamblins Hill, an erosional feature; top right, the lava field of McLennan Hills.

southern margin showing that an explosive eruption had taken place in that area after the formation of the main crater. The area was drained naturally by a stream channel eroded through the north-west wall of the tuff ring but was, until recently, occupied by a swamp with a surface only a few feet above sea level. The crateral slopes of the ring are cliffed and afford clear evidence that the original crater has been enlarged to some extent by erosion.

Tuff erupted from the crater is spread widely over the surrounding area and merges with that from Mt Robertson, although in the centre of the area between the two volcanoes there is now a mantle of tuff only 1–2 ft thick and the underlying Pleistocene silts are exposed in places. To the east and north it unites with ash and tuff deposits from McLennan Hills and the combined ash sheet extends to coalesce with that from the volcanoes of Panmure Basin and Mt Wellington, less than 2 miles distant to the north.

A nest of scoria cones is located in the centre of the Mt Richmond crater and overtops the tuff ring on the south-west side but is separated from the remainder of the ring by a deep moat. The scoria cones are in two distinct groups separated by a broad gulch; they have been built up to a maximum elevation of 150 ft above sea level. The north-eastern portion of the scoria mass is roughly triangular in plan but the outline shows smooth curves which together with convexities on the surface slopes define a number of minor cones. Some of the earlier of these have been buried almost completely by the growth of later cones. The feature has three distinct peaks, one of which bears a small summit crater. The other two are craterless and, presumably, are remnants of larger cones destroyed by eruptions in the centre of the feature where evidence of late activity is preserved in two distinct crateral depressions. The southern face of the mound is marked by a crescentic scarp cutting across one of the craters and giving it the appearance of a breached crater, although it is clear that no lava has flowed from its vent. It is probable that this north-eastern system has been trimmed by the explosive eruptions that accompanied the opening of activity in the complex group of cones on the south of the gulch.

The southern composite structure formed by a second group of vents has been badly defaced by quarrying operations which have removed perhaps one-third of the mass along its north-western flank. At the time of writing, quarries have been reopened and further destruction of interesting detail will no doubt result. The remnant at present surviving has two shallow craters separated by a peak on which a water tower now stands. It is probable, though not clearly shown, that this peak was cratered but the extent of Maori earthwork and later engineering interference makes the original topography obscure. The southern face of the whole feature is scalloped by a crescentic scarp, opposite a well defined lobe in the tuff ring, and has certainly resulted from an explosive eruption at a late stage in the activity of the centre. The site of an explosion pit and the remnant of a scoria mound may be recognised clearly in the area between the tuff ring and the foot of the scarp.

The eruptive history of the Mt Richmond volcano may be reconstructed as follows: Explosive eruptions of a phreatic type formed a wide tuff crater and an encircling tuff ring. Wong (1946), following Hochstetter (1864), wrongly assumes that the phreatic phases of activity of this volcano (as, indeed, he does for Mt Robertson and other basin-forming volcanoes of the

Auckland field) were submarine. He claims support for this view in the presence of raupo remains in muds underlying the tuff near Sylvia Park at the foot of the cone. This in itself shows that the base of the cone was above sea level at the time of eruption and that merely swampy conditions existed near the site. Similar remains have been encountered under tuff at One Tree Hill and in layers between lava flows at Mt Eden, in both cases more than 100 ft above sea level. Bore No. 1106 sunk by the Auckland Metropolitan Drainage Board showed silts and peats to be present beneath tuff at 7 ft below the surface at Annes Creek near the foot of the Richmond tuff cone. It is probable that prior to the eruption of the volcanoes a small stream was entrenched in the soft Pleistocene silts along their contact with the tuffaceous and gritty Waitemata sandstones of Hamblins Hill and that eruption occurred through the low flood plain or broad estuary of this stream.

The main phreatic stage was followed by uprise of lava accompanied by fire-fountaining localised in a succession of vents. This built up the northern group of scoria cones. At least six vents were active in the small area occupied by the group of craters and cones. Doubtless the traces of others are hidden by the mass of fragmentals produced. The last vents in the group to be active were probably those in the centre of the composite cone and were located in the sites of the definite craters that are still preserved. Activity at any one vent was limited both in duration and in magnitude for in no case was either a lava flow produced or a major scoria cone constructed.

An explosive eruption close to the south-west corner of the group destroyed its flank and initiated fire fountaining at a fresh centre. Once more activity became diversified through a number of separate vents so that, again, a complex scoria mound was created.

Lastly, there was another explosive outburst on the southern margin of the cone system which blasted away a portion of that structure and of the encircling tuff ring, thus forming the shallow southern crater. In this area small-scale fountaining built a low cone which was later partly destroyed by weak explosive activity that formed a small pit crater.

The McLennan Hills are immediately adjacent to Mt Richmond and should be regarded as a discrete unit of the same volcano rather than as a separate and distinct system. The two units have many features in common but differ principally in that the vents of McLennan Hills have given rise to a small lava field. This covers approximately 1·5 square miles of area and is situated mainly to the north-east of the cones. The surface of the field shows strong microrelief that has resulted, in the main, from collapse causing the chilled surface to be thrown into numerous troughs and ridges oriented parallel to directions of flow.

A remnant of a tuff ring is preserved on the north-east of the system and in its form suggests that the original tuff crater must have been comparable in size with that of Mt Richmond. The principal lava flow has broken through the northern flank of the low tuff barrier and flowed north and east around the surviving fragment of the tuff cone. A toe of lava exposed in a railway cutting at Sylvia Park railway station, to the north of the centre, is liberally coated with ash, as indeed is most of the surface of flows close to the centre. It is likely that this ash, now consolidated to beds of tuff, was derived from the adjacent Mt Richmond vents, rather than from the vents of McLennan Hills, for the scoria cones of the latter centre are themselves thinly mantled with a similar deposit.

Little now remains of the scoria cones of the McLennan system but aerial photographs taken before spoliation was advanced, show the form of this once-delightful group of cones and make clear the eruptive sequence at the centre. They reveal four closely spaced interlocking cones with five distinct crateral forms. The largest cone was at the south end of the group and had an elevation of between 150 and 200 ft. It possessed a small, but deep, summit crater and was probably one of the earlier features of the group to be built. A lower cone with a broad shallow crater cut into its flank and was probably constructed soon after. This was followed by activity on the west of the group where there was formed a sharp cone with a small breached crater opening into a much larger one scooped out in the centre of the group and interfering with the inner slopes of the three cones already described. This large central crater must therefore have been formed after the cones had been constructed. The group is completed by a broad, low cone with a saucer-shaped crater; this feature at the northern end of the composite structure may have been formed early in the history of the centre and was certainly in existence before activity commenced in the vents of the central crater.

Lava was poured out from many points but at first produced only thin flows piled steeply at the southern foot of the cone system. The principal and more prodigal outflowing was later and issued from the central crater through a breach in its north-west wall. This gave rise to the main lava field.

There can be no doubt that activity at McLennan Hills occurred before the Mt Richmond volcanoes erupted, and, indeed, that activity had ceased in the former area before the vents of Mt Richmond had opened. The tuff crater of Mt Richmond interferes with the tuff cone of McLennan Hills (Fig. 3), the tuff of Mt Richmond covers the basalt flow from McLennan Hills towards Annes Creek, and ash from Mt Richmond veneers both the scoria cones and the main lava field of the other volcano.

Further, it may be concluded that eruptions at McLennan Hills followed after those at Panmure Basin, two miles to the north, for the northernmost lavas of McLennan Hills overlie tuff from Panmure Basin (Fig. 4). These tuffs in turn are spread over timber in position of growth. Radiocarbon dating has fixed the age of the wood as 28,000 ± 1,000 years old, hence it is clear that both at McLennan Hills and at Mt Richmond activity must have occurred since that time. Unfortunately, no data are available to correlate the time of eruption at Mt Robertson with that at the other centres.

The Papatoetoe Group

The Papatoetoe group of volcanoes includes those described by Hochstetter (1864) as the Five Tuff craters at Kohuora. Throughout the group phreatic activity has been dominant and in only one instance (Crater Hill) have other phases supervened. The main features of the system have been described in some detail by Firth (1930).

Pukaki Lagoon (Fig. 5) is a subcircular explosion crater surrounded by a

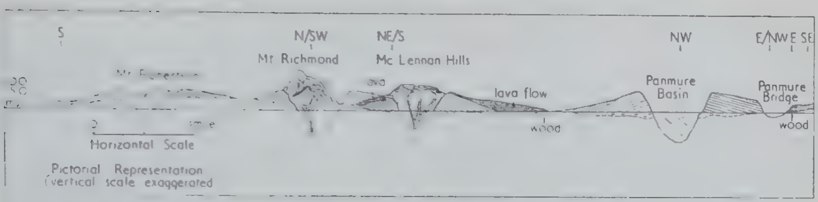

FIG. 4—Synoptic section along lines connecting the Otahuhu-Panmure Basin group of volcanoes. Representation is purely pictorial, vertical heights exaggerated.

tuff ring covering, in all, an area of approximately 1 square mile; the crater is slightly elliptical with greatest diameter 0·4 miles long. The tuff rim is built up to approximately 50 ft above mean sea level and is breached in the southern wall, thus permitting drainage to Pukaki Creek. The floor of the crater is now occupied by a swamp at sea level. No doubt erosion has enlarged the crater to some extent, so that it is now 600 yd in diameter, but erosion has not been great; the original crater was obviously a very large one. The breach was probably caused by sapping due to waters from an initial lake seeping through the porous tuff and on the surface of the underlying Pleistocene silts of the pre-volcanic basement.

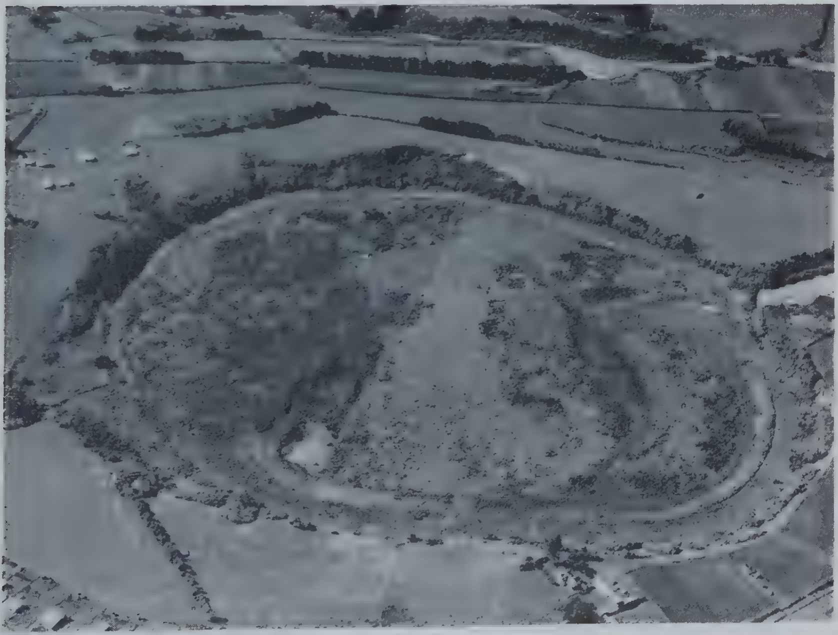

Photo: Whites Aviation Ltd.

FIG. 5—Pukaki Lagoon – a typical tuff crater. The margin of the crater floor has been slightly modified by a one-time speedway. White Pleistocene silts exposed along outlet (right).

The materials forming the tuff cone are predominantly sedimentary in character, mixed with much ash, occasional layers of lapilli and small scoriae. There is no evidence to suggest that multiple vents have been responsible for the crater nor, in the poorly exposed sections through the tuff, is there any clear evidence of repeated explosions. It seems likely that the crater and its surrounding tuff cone are the products of a single explosive episode.

Firth (loc. cit. p. 116–7) points out that, at several localities around the base of the inner crater wall, the tuffs are seen to rest on the underlying pumiceous silts. He notes that the surface of the silts is a somewhat irregular erosion surface which varies in altitude from sea level to about 10 ft above this datum – that is, at a level lower than of the surface generally developed on the silts in the surrounding district. He suggests that either the pumice beds had been built up to their normal higher level and then eroded by streams prior to eruption, or that eruption took place before deposition of subjacent silts had developed the remarkable level plain that characterises the area. Of these alternatives he prefers the second on the grounds that there is no topographic evidence in favour of the first. In effect, it is accepted that eruption in this centre occurred before the development of one of the terraces which have locally come to be regarded as pre-Last Glaciation in age.

In adopting this view, Firth was no doubt influenced both by his interpretation of the section at Panmure Bridge and by the opinions of Turner and Bartrum (1929) concerning the relationship of the tuff of the Shoal Bay craters to the 40–60 ft terrace in the Takapuna district which led these authors to a similar conclusion.

At Panmure the surface of the tuffs of Panmure Basin appears to be perfectly continuous with that of the Pleistocene silts of the Tamaki-Manukau coastal lowlands, and they are therefore considered to have been emplaced before the surface was formed. However, the geomorphic reconstruction of Searle (1956) suggests that this surface may be of a very different type unrelated to the flights of terraces in the Auckland district which are more clearly eustatic in origin. Again, as has been mentioned earlier, the Panmure tuff is now known to overlie trees which have been dated by radiocarbon as 28,000 ± 1,000 years old. It may therefore be accepted with certainty that the eruption of Panmure Basin took place after the onset of Last Glaciation, and also after the formation of eustatic terraces of the earlier cycle.

Concerning the conclusions of Bartrum and Turner on the Shoal Bay craters it should be noted that Bartrum himself (*vide* Wong, 1946) recognised that later evidence from road cuttings at Northcote had proved them to be wrong.

Further, in the Papatoetoe area no section is known in which tuffs are overlain by Pleistocene silts as one might expect had their ejection preceded the deposition of the silts. The suggestion that topographic evidence of erosion of the silts below their plain-like surface, in pre-volcanic times is lacking, also cannot be sustained. Drill holes through the lavas of Wiri Mountain show deep trenching presumably effected during lowered sea levels of sub-Recent times. On the whole, the evidence appears to favour strongly a relatively recent date for the eruptions at Pukaki. Certainly activity there was at a time long after the deposition of the silts and of terrace levels formed on them.

Crater Hill (Fig. 6) has several interesting features. Its large explosion crater is near circular in shape and 600 yd in diameter; together with its surrounding tuff cone it covers an area of approximately one square mile. The tuff ring is built up to nearly 70 ft above the crater floor and to approximately 120 ft above M.S.L. It is entire and the crater at one time contained a swamp and lake which originally discharged by seepage through the tuff on the south-eastern flank although in recent years it has been drained by a tunnel. The tuff deposit is finely bedded and contains a large proportion of basaltic lapilli.

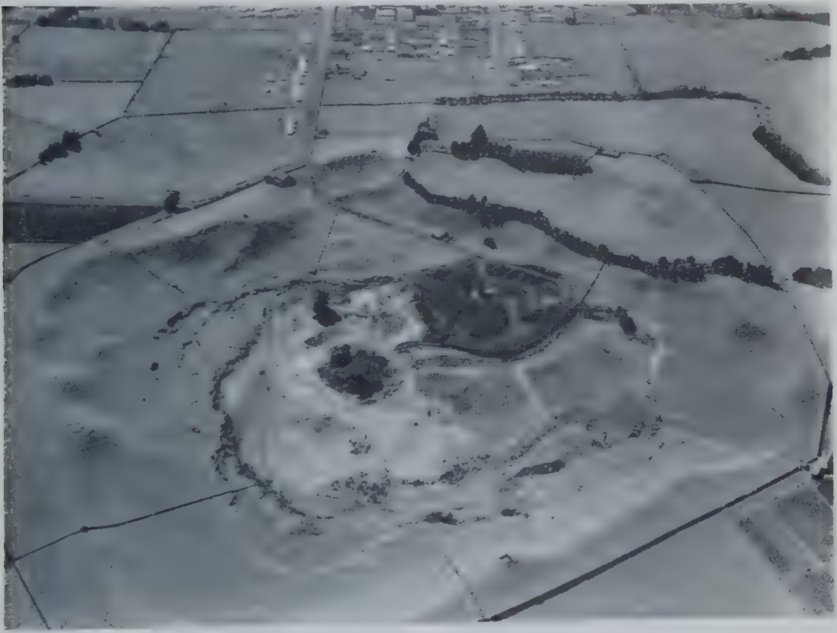

Photo: Whites Aviation Ltd.

FIG. 6—Papatoetoe Crater (Crater Hill). Note explosion pits in tuff ring and lava bench on crater floor. The small clump of trees is established on a mound of lava blocks erstwhile an islet in the crater lake. Dark patch is relic of scoria mound. Original drainage was by seepage below the low saddle on right.

Features within the crater show that the eruptive history of this centre was far from simple. The walls of the crater are skirted by a bench of flow basalts and a rough hummock of basalt blocks emerges island-fashion from the fill forming the crater floor. The tuff crater appears to have been formed by explosions from closed-space foci, whilst two craters of moderate size in the tuff rim – one to the north-east and the other to the east – show that minor phreatic explosions persisted after the main crater-forming eruptions had ceased. A small scoria cone occupies the north-eastern quarter of the crater floor. Quarry faces in the cone show numerous small vents, the sites of which are indicated by irregular intrusions breaking through the scoria beds. At least one of these gave rise to a small lava flow which was, however, contained within the tuff ring. The material of the cone is coarse spatter debris mixed with smaller scoriae and the bedding indicates supply from several sources. Layers of natural brick found, in places, interbedded with scoria, are probably best explained as formed from the materials of small local phreatic eruptions which occurred whilst fountaining vents were still active. There was at least one summit crater on the scoria mound and photographs suggest a breached crater on its western flank. Little now remains of this tiny structure whose height was given by Firth (1930) as perhaps 70 ft above the crater floor on which it rests.

Firth has deduced an eruptive history for the volcano as follows: (1) the formation of the explosion crater; (2) upwelling of lava to form a level floor; (3) foundering of the floor; (4) building of the cone. He suggests that phase (4) may have preceded phase (3) and, in fact, have been the cause of it. This sequence of events appears adequate to explain the main features of the volcanic pile. It seems certain that the outpourings of lava built up flows which were contained within the crater, for there is no evidence of lava outside the tuff ring. On the other hand, the tuff walls of the crater have evidently been worn back by erosion and the lava bench at their foot has been partly uncovered in the process. If the lava had merely been filling the crater from wall to wall one might well have expected the margins of the flow to be exposed and drainage channels to have become established between this and the subjacent tuff. This is not the case, for on all sides tuff is directly in contact with the lava of the benches and has the appearance of covering the basalt. The sequence of events at the centre cannot be as clear cut as the summary above would suggest. Evidence, based on small craters in the tuff ring, has already been given that explosive eruptions continued at the centre after the original crater-forming episodes. It may well be that others of considerable magnitude occurred and that some took place after an original crater had been formed and even after it had been occupied by lava. The surface of the eastern portion of the tuff ring has a distinct wedge-shaped re-entrant very suggestive of a cone-in-cone structure. If this structure is indeed the remnant of a major tuff cone within the main ring then it must have been formed before the scoria mounds were built, and therefore possibly before the lavas were emplaced. Had similar large-scale phreatic eruptions occurred after the lavas had flooded the crater floor then tuff deposits would cover the lava surfaces as, in fact, they appear to do. This explanation is not wholly satisfactory in that if explosion had taken place through the floor of the crater, blocks of basalt would be an expected component of the upper mantle of tuff. In the few cuttings in which the tuff is exposed such blocks of flow rock do not appear to be common.

The scoria cones have been established by an explosive eruption near the margin of the crater floor, for the face of the tuff ring nearby has a clearly defined scalloped surface. They represent a phase of fire-fountaining activity that changed from vent to vent and produced some small flows. It is not considered likely that these vents provided the lava for the main crateral flow but rather (if they are intimately connected with this latter) that they are the product of spatter activity following the effusion of the flow. Such spatter activity could conceivably remove sufficient lava to cause a foundering of the lava floor but it is more probable that this sinking resulted from settling of the crater fill beneath the lava for the margins of the lava bench were clearly solid to a depth of at least 20–30 ft before collapse occurred. Sufficient evidence is not available for confident discrimination between these various hypotheses explaining the complicated relation between the elements of this small volcanic structure.

The Kohuora volcanoes are responsible for the major part of the thick and widespread tuff that covers 2 square miles of area about Papatoetoe township, and of the ash that veneers the surface much further afield. The tuff is chiefly made of finely comminuted sedimentary debris that was disrupted by series of phreatic eruptions. The resulting constructional form is a plexus of ridges and hills in which three groups of explosive craters may be distinguished. These craters probably mark the sites of later eruptions; other earlier centres are probably located under the thick piles of tuff. The largest of the craters is a steep walled, V-shaped depression to the north of the group. It has a swamp-filled floor at 25 ft above mean sea level and is surrounded by a rim built up to 100 ft above the same datum. It is drained by a deep ditch along an original drainage line to the south of the crater. This feature has obviously been greatly modified by erosion but the walls clearly indicate that at least four explosive vents played a part in its formation.

The other noteworthy craters are sited close to the orphanage (eastern crater) and near the cemetery (western crater). The former shows two explosion pits whilst the more clearly defined western feature would seem to have been formed about a single vent.

Of the five volcanic systems in the Papatoetoe group, it may be suggested that those of the Kohuora system erupted first and that within this system eruption at the eastern and western craters preceded that at the northern unit. Crater Hill was probably active before eruptions occurred at Pukaki Lagoon. No evidence is available to relate the time of eruption of the volcanoes in the group with that of the other volcanoes considered in this article.

GENERAL CONSIDERATIONS

Two aspects of the general relationships of these volcanoes are worthy of note.

In the adjoining area the writer (Searle, 1959) attempted to define trend lines for vents of individual volcanoes or for centres that were obviously related to one another in an intimate fashion. He obtained the following results for the three systems:

System	*Bearing of Trend Line*
Mangere	022°
Waitomokia	016°
Ihumatao	030°

The volcanoes of that area are on the whole distributed in a narrow zone about a line trending 020°.

In the present district, for reasons to be discussed later, eruptive activity seems to have been more diffuse, alignments are not so distinct and their directions less consistent. The alignment of the obviously related centres at McLoughlins Hill. Wiri Mountain, and "Ash Hill" is most striking. They lie on a line trending 050°. The main craters of Kohuora system have general distribution along a northerly line but the three major structures – Pukaki Lagoon, Crater Hill, and Kohuora centres as a whole – lie on an east-west line.

The cone-building centres of Mt Richmond have a general alignment of 025° whilst the Mt Richmond-McLellan Hills line trends 050°. However, a narrow zone about a line trending slightly east of north drawn through Mt Robertson would include Mt Richmond, McLennan Hills, Mt Robertson, the main Kohuora vents and McLoughlins Hill. Further north, Mt Wellington and Purchas Hill would be included. In spite of the apparent anomalies it would seem reasonable to infer tentatively that the location of eruptive centres in the present district has been governed by some such directional control which is conformable with the pattern shown by the distribution of vents in individual centres demonstrated in the adjoining area.

It is of interest to note that in portions of the Auckland volcanic field outside the boundaries of these two districts a similar northerly trend is shown by the distribution of vents in individual centres and of centres closely related to one another. The following examples may be cited:

Shoal Bay craters and Pupuke – 010°
Mt Eden system (at least 3 vents) and Grammar School spatter cone – 010°
East Tamaki Volcanoes – 013°
Mt Wellington – Purchas Hill system – 005°.
Little Rangitoto – Orakei Basin – 015°

Discussion of the significance of these trend lines must await fuller study of other parts of the Auckland volcanic field. Meanwhile the results may be accepted as suggesting that some pattern in the distribution of centres does exist locally and that the possibility of deciphering a more wide-spread pattern is not as remote as earlier workers assumed (e.g., Hochstetter, 1864; Wong, 1946).

Lastly, it has already been pointed out that the Otahuhu-Manurewa area in which these volcanoes occur is part of the extensive basin of Pliocene-Pleistocene sedimentation which encompasses the Manukau Lowlands and that it is margined to the north by the emergent Auckland block of Waitemata sedimentary rocks and to the south by a ridge of rocks of the same kind. It will be noted that in this district, areas characterised by vulcanism of the phreatic type on the one hand, and of the lava-producing type on the other, are clearly differentiated. The lava-producing volcanoes are restricted to areas close to the boundaries of the Waitemata formation whilst eruptions of the purely phreatic type predominate in areas more remote from the margins of the basin. Thus it would seem that the type of activity was in a large measure determined by the covering rock. Where passage was made solely through Waitemata strata or where the superficial cover of younger sediments was necessarily thin, then conduits seem to have remained open longer, and activity, although at first phreatic, became dominantly effusive.

Where the cover of silts has been thick, eruptions have been largely abortive and restricted to explosive outbursts or, at the most, to have persisted long enough to permit only minor effusion, e.g., Crater Hill.

The same pattern appears to be general in other local areas where Pleistocene sediments occur, although there are obvious exceptions – the St Heliers volcano, for example, was purely phreatic although it is located in a wholly Waitemata terrain, whilst Puketuku (standing on a basement of Pleistocene silts) produced much lava. By and large, however, the following generalisation is true: where Plio-Pleistocene or Recent sediments are thick, eruptions were predominantly phreatic, e.g. Shoal Bay Crater, Pupuke, Panmure Basin, Pigeon Mountain; where they are absent or thin, activity was dominantly effusive, e.g. Mount Eden, One Tree Hill, Mt Victoria, etc.

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RECONNAISSANCE SURVEY FOR OPAQUE ORE MINERAL CONTENTS AND RADIOACTIVITY IN BEACH SAND DEPOSITS BETWEEN THE CATLINS AND MATAURA RIVER MOUTHS, OTAGO AND SOUTHLAND, NEW ZEALAND

By W. R. B. MARTIN, Victoria University of Wellington

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Abstract

No economically attractive quantities of metalliferous ore mineral are found in the extensive sand accumulations between the mouths of the Catlins and Mataura Rivers. A dark green amphibole is the outstandingly predominant heavy mineral throughout. Definite radioactivity is indicated at four places, in three cases in − 60 B.S. mesh "heavy" fractions and in one case in + 44 B.S. mesh unconcentrated material.

INTRODUCTION

Early in 1957, accompanied by Mr D. S. Nicholson, the author inspected and collected samples from beach and dune sand deposits on the Otago-Southland coast between the mouths of the Catlins and Mataura Rivers, for the purpose of obtaining an indication of the nature and extent of any iron or titaniferous ore minerals they contained, as part of a comprehensive survey of these ore minerals in New Zealand beach sands. Only those deposits which topographical maps indicated to be of any appreciable size were sampled. Estimates of sand quantities were not made as the beaches west of Bluff had been found to contain no commercially attractive quantities of heavy minerals. (Martin and Long, 1960.)

Other "heavy" minerals, separated in the course of concentrating and isolating the opaque ore minerals, have been roughly identified by inspection under a petrological microscope, to give some indication of the nature of the "heavy" minerals present in these sediments, but no diagnostic constants were measured.

Hutton and Turner (1936), Coombs (1954) and Brothers (1959) have studied the heavy minerals in source rocks feeding decay and erosion products to the Mataura River, but it appears that, apart from one sample (S. 170 – 026393) of Brothers (1959) from country that now drains into the Pomahaka River, little work has been done on the detritus being fed down the other rivers of this area or on the coastal sediments themselves.

EXPERIMENTAL PROCEDURE

Samples of about 4 lb weight taken in the field were thoroughly washed and dried in the laboratory and reduced to suitable sized working samples by means of a sample splitter.

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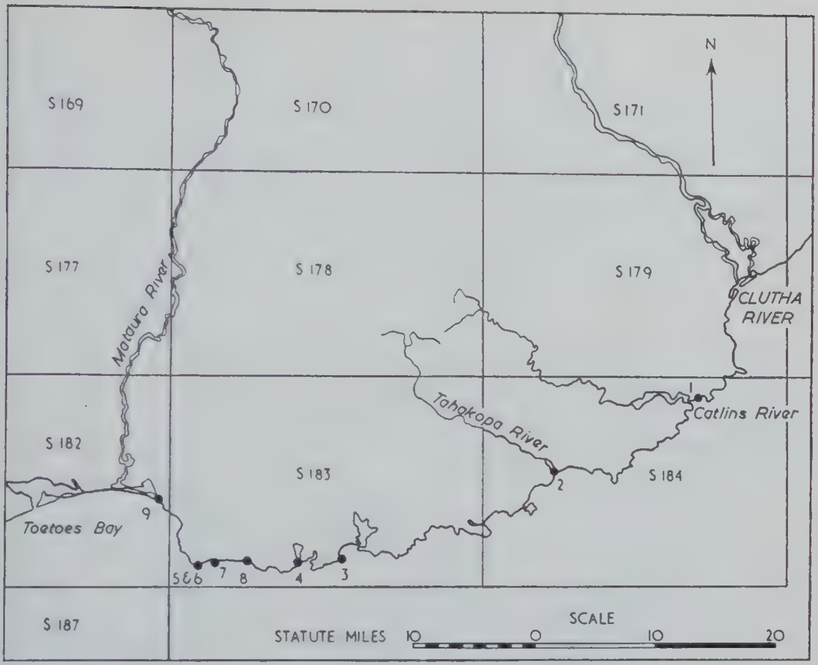

FIG. 1—Map showing coastline between the mouths of the Catlins and Mataura Rivers and sample localities.

These were sieved into three fractions, + 44, – 44 + 60, and – 60 B.S. mesh, and weighed.

All primary fractions so obtained were counted for radioactivity.

Each – 60 fraction was then passed through the author's heavy liquid separator operating on bromoform to extract "heavy" minerals of S.G. greater than 2·9. Both "heavies" and "lights" so obtained were weighed and counted for radioactivity.

Where the "heavies" exceeded 2% of the – 60 mesh material of the original sample (except for sample 9 with only 2·9% "heavies" content in a very small fraction of – 60 material) they were separated in the author's modification of Officer's high intensity magnetic separator, after ferrimagnetic minerals had been removed by a hand magnet with a field strength of 700 oersteds. All fractions were weighed to assess their percentage by weight of the total "heavies".

Each magnetically divided fraction was counted to detect any significant radioactivity.

All heavy fractions, other than the strongly magnetic ones, were then examined under the petrological microscope to make a rough assessment of the predominant transparent minerals present; counts of about 200 grains were made to determine the proportion of opaque ore grains present.

Radioactivity counting was performed as described by Martin and Long (1960).

Radioactivity was considered to be probably present when a difference in counting rate over background exceeded 2 and reliably so when the difference exceeded 3, these conveniently rounded off numbers being the 79% and 94% statistical limits of confidence at the 16 counts per minute (c.p.m.) background level. At the low 13·6 c.p.m. background level, the confidence limits are 87% and 97%.

RESULTS

Table 1 gives the location and description of the samples.

Tables 2 and 3 set out the results of the investigations.

Table 2 shows:

(1) The mechanical analyses into + 44, − 44 + 60, and − 60 B.S. mesh fractions:
(2) The proportions by weight of the − 60 fractions recovered as material heavier than S.G. 2·9 in a stated number of passes through the continuous liquid separator;
(3) Estimates of the total percentage of minerals heavier than S.G. 2·9 in these fractions based on performance of that separator tested to three extractions on similar samples;
(4) The proportions by weight of ferrimagnetic, intermediate susceptibility and low susceptibility minerals in the heavier than bromoform fractions above. In no case was any collectable quantity of material with a susceptibility normally associated with ilmenite present.
(5) Radioactivity counts for all the above fractions except for the heavy fractions where they were further subdivided.

Table 3 shows for the samples listed in Tables 1 and 2:

(1) Rough identification under the petrological microscope of the more abundant transparent minerals;
(2) Estimation, by counting about 200 grains, of the percentage of opaque grains present in the intermediate and low susceptibility or undivided heavy fractions. The percentage opaque is a grain count figure only; the opaque grains were in general much smaller than the associated transparent grains and probably much denser; the "% by weight" figure would therefore probably be 50–100% of the grain count percentage given.

Not shown in Table 2 are the radioactivity counts obtained for the "lights". "Lights" from sample 1 were lost; count differences were negligible for all others, except sample 8, which recorded 2·7.

Where indicated by * in Table 2, pairs of figures are given for radioactivity count differences; these are where the fractions from the two passes through the bromoform separator had not been mixed and could be counted separately.

TABLE 1—Catalogue of Samples Taken, Localities in Terms of Local Geography, and Description of Sampling Method

Sample No.	Geographical Locality	Approximate Location*	Lab. No.	Sampling Date
1	Catlins River Mouth (New Haven) Vertical slice taken from 2 ft 6 in. deep hole in damp sand at seaward toe of sand dunes facing the beach the east side of the Catlins River beyond the end of the road to Surat Bay. A considerable quantity of sand in the area. Some dark mineral concentrated in beach ripples and dry dunes slides.	S. 184–515.972	MN 201	19/1/57
2	Papatowai Vertical slice taken from a 3 ft deep hole in damp sand on beach at the south-west side of Tahakopa River. Evidence of dark mineral concentrated in surface ripples. Sand in the area is mainly along the beach north-east of the river. There is no great quantity.	S. 184–303.862	MN 202	19/1/57
3	Porpoise Bay Vertical slice taken from 2 ft 6 in. deep hole in damp sand on beach at south end of Porpoise Bay a little north of the flat low rocky point dividing it from Curio Bay.	S. 183–994.736	MN 203	19/1/57
4	Haldane Beach Vertical slice from a hole 2 ft deep in damp sand halfway along the spit on east side of the estuary between it and the sea and on the seaward slopes of the spit a little above high tide mark. No evidence of dark mineral. There is a considerable quantity of sand in the area.	S. 183–936.730	MN 204	19/1/57
5	Waipapa Beach A vertical slice from 2 ft deep hole on active beach at about high tide level at a place about ½ mile east of the lighthouse. The beach sand appeared very coarse.	S. 183–790.729	MN 205	20/1/57
6	Waipapa Beach Slice of top 6 ft of a steep face of a high dune (approx. 50 ft) including a dark band, some chains inland from beach. There is a considerable quantity of sand in the area.	S. 183–790.729 (Just inland in dunes from No. 5)	MN 206	20/1/57
7	Waipapa Beach The location was in direct line with grass road shown on map. A sample of surface concentrate behind dune, showing evidence of dark mineral, about middle of a group of high dunes between swampy flat and the coast.	S. 183–824.738	MN 207	20/1/57
8	Waipapa Beach Surface sample from 3 ft deep face of a low mound near the ladder of an abandoned dredge.	S. 183–860.738	MN 208	20/1/57
9	Toetoes Harbour (Mouth of Mataura River) Vertical slice from a 3 ft deep hole in damp sand of low dunes at bend just inside channel mouth on the east side of the channel near end of road beyond Fortrose.	S. 182–735.823	MN 209	20/1/57

*On N.Z. 1 mile/in. Topographical Maps giving: Map No.; West to East grid reference; South to North grid reference.

TABLE 2—Restricted Mechanical Analyses and Percentages by Weight of "Heavy" Mineral Fractions Separated from − 60 B.S. Mesh Material by Bromoform Sink/Float and High Intensity Magnetic Methods, Together with Radioactivity Counts on All Fractions for Samples as Listed in Table 1

Sample Reference No.	Mechanical Analyses With B.S. Sieves, wt. % of Total Sample Weight and Radioactivity Counts (c.p.m.)									Separation of − 60 Material in Automatic Heavy Liquid Separator† and Radioactivity Counts (c.p.m.)						Separation of the − 60 "Heavy" Fraction by Magnetic Means							
	+ 44			− 44 to + 60			− 60			"Heavy" Fraction. S.G. > 2·9						Ferrimagnetic, Attracted by Magnet, 700 Oersted Field Wt. % Magnetite	High Intensity Separator.† Triangular poles Set @ 12°, $^{7}/_{32}$ in. gap 5300oe. Field. Also Radioactivity Counts (c.p.m.)						
																	V. High Susceptibility Throw > 5·0 cm	Intermediate Susceptibility Throw 2·7-5·0 cm			Low Susceptibility Throw < 2·7 cm		
	Wt. %	Background	Sample Minus Background	Wt. %	Background	Sample Minus Background	Wt. %	Background	Sample Minus Background	No. of Passes Through Separator	"Heavies" Actually Recovered. Wt. of − 60	Adjusting Factor Used	Estimated Total "Heavies", Wt.% of − 60	Background	Sample Minus Background			Wt. %	Background	Sample Minus Background	Wt. %	Background	Sample Minus Background
	A			B			C			D						E	F	G			H		
1.	<.1	n.d.	n.d.	1.0	18.0	0.9	99.0	13.6	4.0	1	7.4	1.6	11.8	n.d.	n.d.	4.0	neg.	27.9	13.6	0.4	68.1	13.6	4.5
2.	0.4	n.d.	n.d.	5.1	n.d.	n.d.	94.5	13.6	2.7	2	8.3	1.15	9.5	n.d.	n.d.	3.1	neg.	23.8	13.6	4.4	73.1	13.6	4.9
3.	0.2	n.d.	n.d.	2.4	16.1	3.5	97.4	16.1	0.3	2	10.0	1.15	11.5	n.d.	n.d.	4.8	neg.	31.0	16.1	*2.0 0.7	64.2	16.1	*3.0 0.8
4.	20.7	13.6	5.5	59.2	16.0	2.6	20.1	16.0	1.4	2	2.0	1.15	2.3	n.d.	n.d.	3.9	neg.	16.4	16.0	*2.1 0.8	79.7	16.0	*1.5 1.7
5.	17.2	18.5	2.0	37.1	16.0	1.6	45.7	13.6	2.2	2	0.6	1.25	0.7	16.0	*3.0 2.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6.	1.6	17.5	1.0	30.4	16.0	1.1	68.0	16.0	2.6	2	2.7	1.15	3.1	n.d.	n.d.	1.7	neg.	23.0	16.0	*3.7 2.0	75.3	*13.6 16.0	*1.8 1.9
7.	0.7	17.0	0.7	6.1	16.0	1.0	93.2	16.0	1.4	2	30.9	1.15	35.5	n.d.	n.d.	1.9	neg.	19.6	16.0	*0.8 0	78.5	16.0	*3.1 0.8
8.	16.0	13.6	1.0	41.6	16.0	1.1	42.4	16.0	0.9	2	8.1	1.15	9.3	n.d.	n.d.	2.2	neg.	14.8	16.0	*1.5 0.7	83.0	16.0	*0.5 0.3
9.	95.1	13.6	0.4	1.0	16.0	2.9	3.9	n.d.	n.d.	2	2.3	1.15	2.6	16.0	*4.1 2.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

*First and second "heavies" counted. †Separators used were designed by the author and will be described in subsequent papers.
n.d. = not determined.

TABLE 3—Rough Identification of Transparent Minerals by Petrological Inspection in Clove Oil for the "Heavy" Mineral Fractions Displayed on Table 2 and Estimation of the Proportions of Non-ferrimagnetic Opaques in them by Counting approx. 200 Grains. p = predominant. a = abundant, m = minor.

Sample Number	Locality of Sampling	Column in Table 2	Magnetic Susceptibility in Table 2	Amphibole* (Mainly Very Dark Green)	Biotite	Chlorite	Epidote	Garnet	Pyroxene†	Kyanite	Muscovite	Olivine	Staurolite	Titanite	Tourmaline	Zircon	Unidentifiable Cloudy Grains	Opaques; % of Grains in Fraction
1.	Catlins River	G	Intermediate	p				m	m									<1·0
	Mouth	H	Low	m	m		a	m						m		m		<1·0
2.	Papatowai	G	Intermediate	a			m	m	m									2·7
		H	Low	m			a							m			p	1·1
3.	Porpoise Bay	G	Intermediate	p				a	a‡									1·9
		H	Low	m			p							m				<1·0
4.	Haldane Beach	G	Intermediate	p			m	a	m									8·8
		H	Low	a			a									m	p	<1·0
5.	Waipapa	G & H	Mixed				Only opaques determined											5·2
6.	Waipapa	G	Intermediate	p			a	a	a									8·4
		H	Low	m			a						m?			m	a	<1·0
7.	Waipapa	G	Intermediate	p			m	m	m	m								2·9
		H	Low	p			m	m				a		m			a	<1·0
8.	Waipapa	G	Intermediate				Only opaques determined											4·7
		H	Low				Only opaques determined											<1·0
9.	Toetoes	G & H	Mixed	m	a	a			m		m			m	m	m		2·8

*Most of the amphibole appears to be hornblende but no quantitative measurements were made. †Most of the pyroxene appears to be hypersthene but no quantitative measurements were made. ‡Mostly markedly pleochroic.

DISCUSSION

Except for samples No. 4 and 9, both from river spit beaches, the particle size of the samples is predominantly − 60 B.S. mesh; only − 60 B.S. mesh fractions were examined for opaque ore minerals which concentrate largely in the smaller fractions of a beach sediment as a result of the processes of their derivation and transport.

It is clear from Tables 2 and 3 that no sample contains any commercially attractive concentration of opaque ore minerals. Even sample 7, a dark wind-blown concentrate containing some 35% of minerals heavier than bromoform, contains only $[1{\cdot}9 + (2{\cdot}9 \times {\cdot}19) + (1 \times {\cdot}78) = 3.23] \times {\cdot}35 = 1{\cdot}13\%$ of opaque mineral, most of which is strongly magnetic. Chemical identification of any of these opaques did not appear warranted.

A dark green amphibole – probably hornblende – is the predominant heavy mineral in the series from Catlins River to Waipapa and, in the heavy mineral concentrates, epidote is also abundant. Garnet and pyroxene are abundant only between Porpoise Bay and Waipapa.

Significant radioactivity is associated with the "heavies" at Catlins River Mouth and Papatowai, and apparently also at Porpoise Bay and in the Waipapa dune material. The only apparent correlation is with the occurrence of minor titanite which in other parts of the South Island has radioactivity associated with it (Hutton, 1950). No attempt was made to concentrate or otherwise trace the source of the activity. The outstanding indicaion of radioactivity is the unconcentrated coarse + 44 B.S. fraction of sample No. 4 from the lagoon spit at Haldane Beach. The finest fraction of the same sample gives little evidence of activity; however, the middle size does indicate some activity. At the time of writing the author rechecked this fraction in new low background surroundings and confirmed a significant count. The occurrence of activity in such relatively coarse sediments seems to indicate a nearby source and that the element responsible is increasingly leachable or otherwise removed with reduction in particle size. Again no attempt was made to find where the activity resided. All separated products of samples listed have been lodged in the Geology Department, Victoria University of Wellington.

CONCLUSIONS

The deposits appear to contain no economically interesting quantities of opaque metalliferous ores; in fact, the indications did not justify identification of those separated.

The dark mineral that in places gives a superficial indication of an interesting opaque mineral content is a dark green amphibole.

Definite radioactivity is found to be present in − 60 B.S. mesh material from the Catlins River Mouth and Papatowai sediments.

Coarse, + 44 B.S. mesh, material from Haldane Beach gave the highest significant radioactivity count.

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THE SOUTH-WEST EXTENSION OF THE AWATERE FAULT

By R. P. SUGGATE, H. S. GAIR, and D. R. GREGG, New Zealand Geological Survey, Department of Scientific and Industrial Research, Christchurch

(Received for publication, 13 December 1960)

Abstract

The Awatere Fault has been traced south-west to join the Alpine Fault at the Clear Grey River. The metamorphic zone boundaries of the Alpine schists are displaced dextrally by about four miles, but the Alpine Fault is not displaced.

INTRODUCTION

The Awatere Fault was dramatically introduced to the early settlers of Marlborough by the 1848 earthquake, during which horizontal and vertical movement took place at the fault (*see* F. A. Weld *in* Lyell, 1868, p. 89). The fault was named the Awatere Fault by McKay (1892, p. 18) who considered it to extend across Cook Strait to join the Wellington Fault; this correlation has also been made by Lensen (1958a). South-west from the Awatere valley, the fault was shown by McKay as joining the Hope Fault, but Wellman (1953, p. 271) tentatively showed it to extend to the Alpine Fault near the Maruia River, without displacing the Alpine Fault. Lensen (1958b, p. 314) showed the Awatere Fault to join the Alpine Fault at a pronounced bend in the latter, a bend that lies between Lake Daniells and the Glenroy River. Kingma (1959, Fig. 11) showed the Awatere Fault intersecting the Alpine Fault and displacing it dextrally by five or six miles.

Geological mapping during 1959 for the 1 : 250,000 Geological Map of New Zealand has traced the western section of the Awatere Fault, and has shown that it joins the Alpine Fault at the Clear Grey River (Figs. 1 and 2). This section of the fault is based on late Quaternary fault traces, crush zones, and displacement of metamorphic boundaries. Petrological examination by Dr J. J. Reed, N.Z. Geological Survey, Lower Hutt, has confirmed the metamorphic ranks of the samples from which the displacement of metamorphic boundaries had been deduced in the field.

THE LOCATION OF THE WESTERN SECTION OF THE AWATERE FAULT

From Wellman's data (1953) the Awatere Fault is known from Late Quaternary fault traces as far west as two miles west of Malings Pass. Wellman also lists an offset of the Waiau valley, but the bend in the valley could be due to differential erosion. Further west no fault traces are known in the bush-clad country, but some that may be associated with the Awatere Fault are known above the bush line both north and south of the

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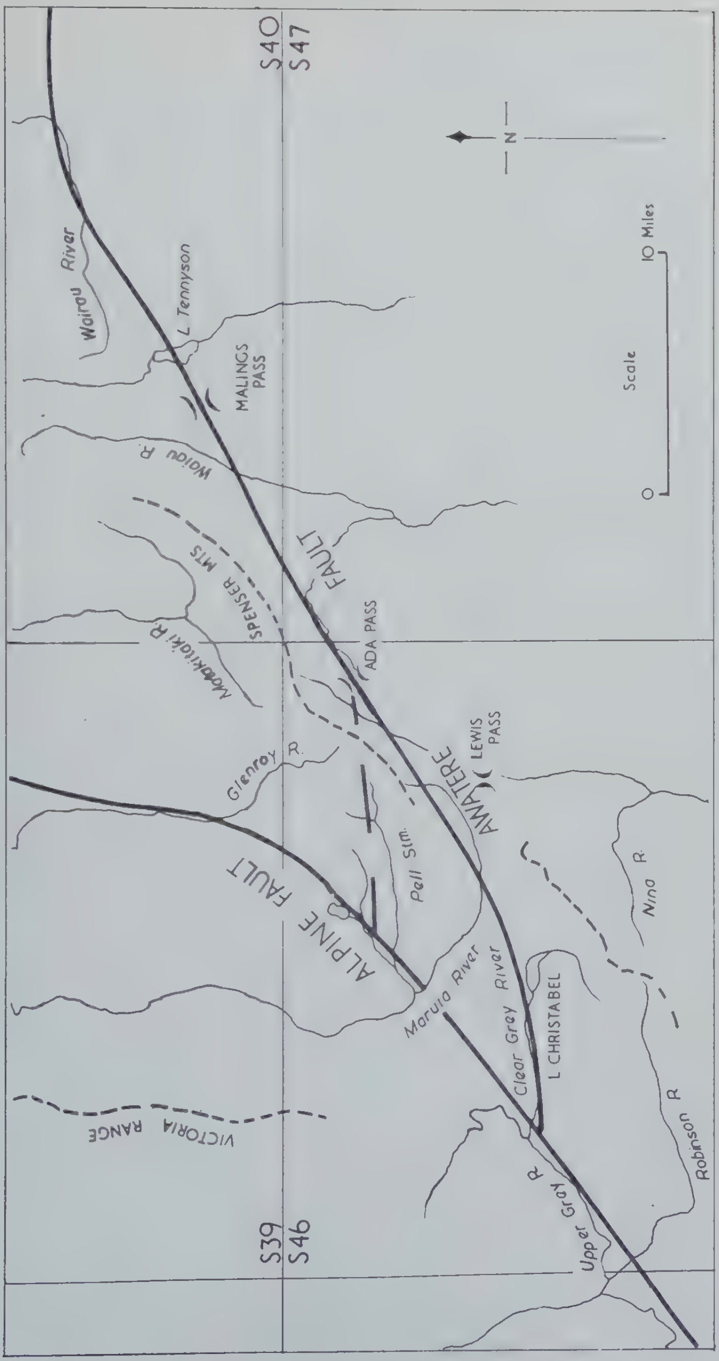

FIG. 1—Locality map.

west-flowing reach of the Maruia River (Fig. 2). Those to the north of the river are (1) the "rent" shown on the map of Una Survey District by Henderson and Fyfe (1935), at the head of Glenroy Stream two miles west of Ada Pass, (2) the recent trace at the saddle at the head of Pell Stream noted by Mr H. E. Fyfe (pers. comm.) on the fault line shown on the Una Survey District map, and (3) the trace known from an oblique aerial photograph of the head of the Left Hand Branch of the Maruia River. Those to the south of the Maruia River are known from vertical aerial photographs; they are (4) a trace on the spur between Three Mile and One Mile creeks, (5) a trace cutting the ridge about half a mile north of trig Lucretia (this lies on a fault on Henderson and Fyfe's map of Travers Survey District (1935)), and (6) another trace about a mile north-west of 5. It is improbable that all these lie on major faults, particularly as those to the south of the Maruia River closely parallel the bedding, and other evidence for a major fault requires to be considered.

The boundary between the "sub-schist" and "unmetamorphosed greywacke" across the ridge between Lake Christabel and the Maruia River is considered by Mr H. E. Fyfe (pers. comm.) to be faulted, and not transitional as shown on his map of Travers Survey District (Henderson and Fyfe, 1935). In particular he has noted a marked metamorphic contrast between the rocks on the two sides of the saddle on the crest of this ridge.

In the Clear Grey valley the principal evidence for a fault lies in the lateral displacement of metamorphic boundaries (see below). The position of the fault-zone is marked by greenish crush-rock exposed 1½ miles upstream from the road bridge on the north bank of the river. In this exposure and in a small but not shattered outcrop a few chains downstream, the rock is not obviously schistose, and belongs to the chlorite subzone 2. To the north, beyond the fault, the rock is of biotite zone, and to the south, of chlorite subzone 3, so that clearly the chlorite subzone 2 rock is fault-involved. About a quarter of a mile upstream from the exposure of crushed rock, biotite schist from the north bank of the river is reported by Dr Reed as having possibly undergone retrograde metamorphism. The outcrop is more than a mile south-east of the Alpine Fault, and as all the retrogressively-metamorphosed rocks noted by Reed (1958) are within half a mile of the Alpine Fault, the lowering of rank at this outcrop may be associated with a major fault other than the Alpine Fault.

From the above evidence it is concluded that a major fault extends along the valley of the Clear Grey River and the northern edge of Lake Christabel, across the ridge to the Maruia River a mile downstream from the hot springs, thence to the head of the Left Hand Branch of the Maruia River and across Cannibal Gorge to Ada Pass. This is considered to be the main line of the Awatere Fault. The Maruia hot springs issue probably from a minor fracture zone, but the main channel for underground heat may well be the Awatere Fault itself. Although no warm spring is known, a smell of hydrogen sulphide is strong close to the line of the fault on the river flats on the north side of the Clear Grey River two miles upstream from the road bridge. A hot spring, not obviously associated with the Awatere Fault

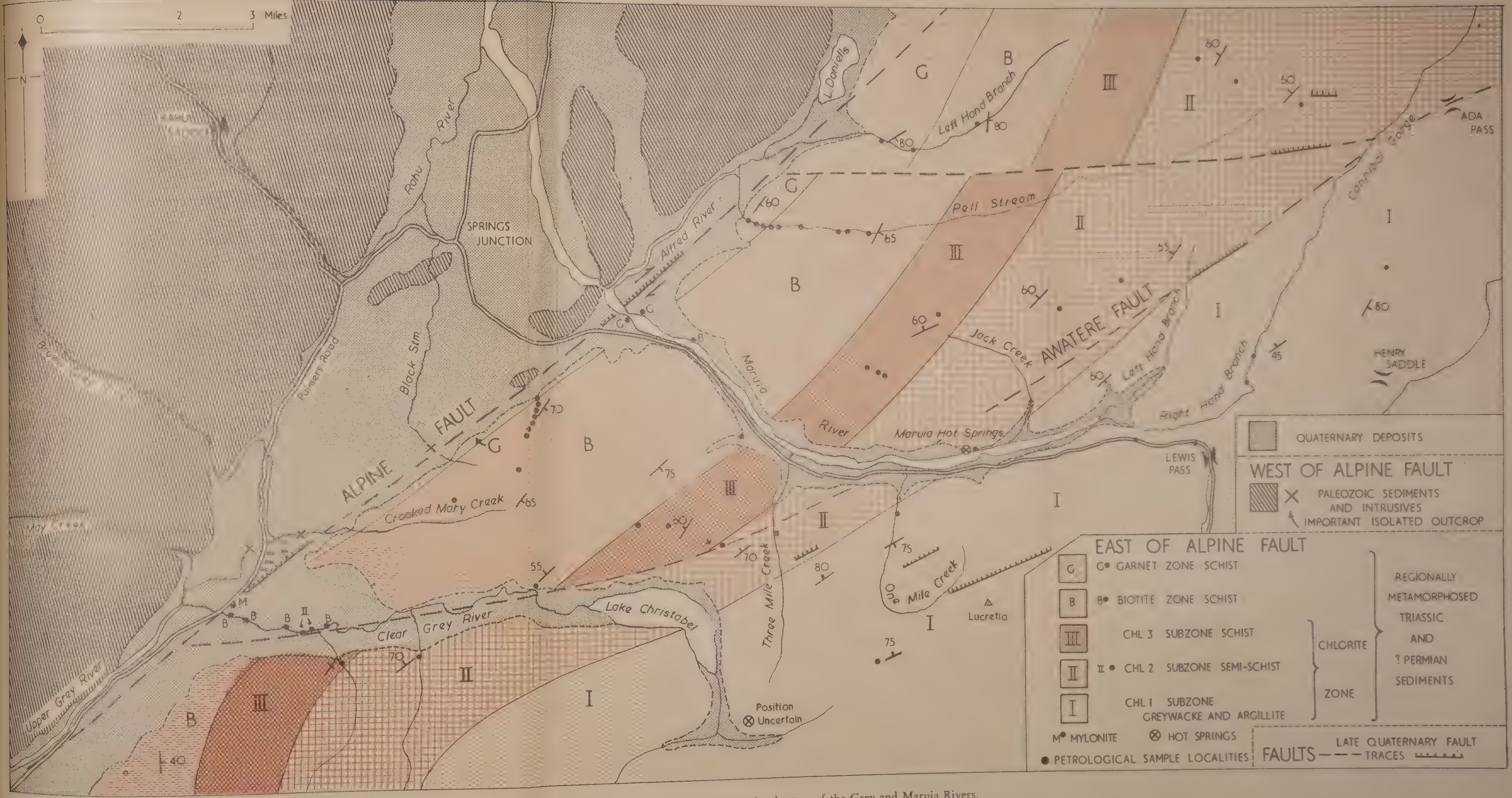

FIG. 2—Metamorphic Zones in the headwaters of the Grey and Maruia Rivers.

as mapped, is reported (H. E. Fyfe, pers. comm.) in a position one mile south-south-east of the south end of Lake Christabel.

A branch fault is tentatively mapped as extending westwards from the Awatere Fault at Ada Pass, through the fault trace at the head of Pell Stream, and along the southern slopes of the Left Hand Branch of the Alfred River. This is thought to meet the Alpine Fault between the Left Hand Branch of the Alfred River and Pell Stream. Apart from the fault trace, the evidence for the fault is an apparent offset of about a mile in the metamorphic boundaries, as discussed below.

DISPLACEMENT OF METAMORPHIC BOUNDARIES

The geology of some of the country crossed by the south-west extension of the Awatere Fault has been mapped by Fyfe (Henderson and Fyfe, 1935) and the metamorphic rocks have been described by Reed (1958), who divided them into chlorite subzones, biotite zone, and garnet zone. The Clear Grey River is outside the areas described by Fyfe and Reed.

The positions of samples that have been petrologically examined are shown on Fig. 2, apart from eight samples from the garnet zone in Pell Stream, omitted because of the scale of the map. Most of the samples are those discussed by Reed (1958), but a further 30 samples, principally from Pell Stream and from the valley of the Clear Grey River, have been examined. The metamorphic ranks of all the samples are consistent with the zoning shown in Fig. 2.

The displacement of metamorphic zones at the Awatere Fault along the Clear Grey River is shown in Fig. 2. The positions of the metamorphic boundaries were drawn on field evidence and the metamorphic ranks of samples were confirmed by petrological examination by Dr J. J. Reed (pers. comm.). The boundaries between biotite zone and the chlorite subzones 2 and 3 are displaced dextrally by about 4 miles.

The branch fault between Pell Stream and the Left Hand Branch of the Alfred River displaces the boundary between garnet and biotite zones by between one and one and a half miles. The position of this boundary is accurately known in Pell Stream, and in the Left Hand Branch it must be east of the most easterly sample from garnet zone.

THE RELATION OF THE AWATERE AND ALPINE FAULTS

In the area under discussion the Alpine Fault is a clear-cut boundary between Alpine schists to the east and Paleozoic sediments (marble, argillite, greywacke, in part regionally- and contact-metamorphosed) and plutonic rocks to the west. The Awatere Fault, on the other hand, is the boundary between rock sequences that are similar on both sides, and is thus less important than the Alpine Fault. Kingma (1959) has sought to minimise the importance of the Alpine Fault, part of his argument being that its line is discontinuous, being offset by the Awatere and other faults. Thus it is important to note in detail the evidence for the position of the Alpine Fault in the area where the Awatere Fault joins it.

Although widespread Quaternary deposits obscure the Alpine Fault in the older rocks for most of its length, movement displacing these Quaternary deposits is known to be almost on the line of the underlying fault wherever this is closely defined in the major valleys. At these places the older rocks are characteristically altered by faulting. To the west of the fault igneous rocks develop rounded blobs of quartz in a dark matrix. Immediately east of the fault, greenish colours characterise massive poorly schistose (retrogressively-metamorphosed) mylonitic rock, in places interstratified with schists with crinkled schistosity; these crinkled schists gradually give place eastwards to unaffected schists (cf. "curly schist" of Wellman, 1955, Fig. 6).

Near the Awatere Fault, the position of the Alpine Fault is defined most closely by the Late Quaternary fault trace to the south-east of the swamp three-quarters of a mile north-east of the Clear Grey River, but no displacement can be certainly recognised on low terraces close to the river itself. In locating the fault from outcrops of pre-Quaternary rock, several exposures are critical. Green albite-chlorite mylonite, shattered and poorly schistose in hand specimen, crops out on Palmers Road a quarter of a mile north of the Clear Grey River. In the river itself dark crinkled biotite schist is exposed a quarter of a mile upstream from the road bridge. These two outcrops make it certain that the Alpine Fault lies no further east than the fault trace. Half a mile to the north-east the fault trace is only a quarter of a mile east of an outcrop of marble in Crooked Mary Creek, and continuing the direction of the trace a further 2 miles, it passes close to the east of an outcrop of dioritic igneous rock in the upper reaches of Black Stream; from there the line can be continued directly to the fault trace at the Maruia River discussed by Wellman (1952).

The position of the Alpine Fault is thus considered well defined north of the Clear Grey River, but to the south it appears to be concealed for all the eight miles to the Robinson River by young fans still growing as a result of rapid erosion along the steep north-western front of the Southern Alps. Outcrops of dark igneous rock with rounded blobs of quartz on the west bank of the Upper Grey River about two miles downstream from the junction of the Clear Grey and Brown Grey rivers limit the position of the fault to the north-west, and if the line of the Alpine Fault is extended south-west from the Clear Grey River, it passes a quarter of a mile south-east of these outcrops. Further extension south-west (Fig. 1) in the direction of the Nancy River fault traces (Wellman, 1953, ref. No. 81; note this trace is in Sheet S52 not S46) carries it about midway between gneissic granite in the Upper Grey River one and a half miles upstream from the Robinson River and biotite schist in the Robinson River nearly two miles upstream from the Upper Grey River.

It is considered that the Alpine Fault is fixed accurately enough to make it possible to affirm that any dextral offsetting of it by the Awatere Fault cannot exceed a quarter of a mile, and that no offsetting at all is likely. This is in opposition to the suggestion of Kingma (1959, p. 31) that the Alpine Fault "is cut by the Marlborough faults and divided into segments, and does not form a continuous line . . .", and that it is offset five to six miles (see Kingma, 1959, Fig. 11) at the Awatere Fault. Nevertheless the relations of the Alpine and Awatere faults, and the offsetting of metamorphic boundaries at the Awatere Fault, clearly remain features of major structural importance. A similar offsetting of metamorphic boundaries at a branch of the Taramakau-Hope Fault at the Taramakau River is briefly mentioned by Wellman *et al.* (1952, p. 216). To discuss these features fully would involve problems of the age of metamorphism, of the time of tilting of the schist zones, and of the relative horizontal and vertical movements at the faults. These problems require consideration of a far larger region than that discussed in this paper, and are vital to any discussion of the structure of the South Island.

Acknowledgments

The writers have obtained much useful information from the field-sheets of the southern part of the Murchison Subdivision which were prepared by Mr H. E. Fyfe in 1928–1930. The writers are indebted to Mr Fyfe for making this information available, and to Dr J. J. Reed for his petrological determinations.

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FERGUSONITE AND SAMARSKITE FROM CANAAN, PIKIKIRUNA RANGE, NELSON

By W. A. Watters[1], H. J. Todd[2], and E. J. Sixtus[3]

(Received for publication, 21 December 1960)

Abstract

Fergusonite and samarskite were found in the heavy concentrates of stream gravels at Canaan, on the Pikikiruna Range, north-west Nelson. The physical properties of the minerals are briefly described, and X-ray diffraction data and the results of spectrographic analyses are given.

INTRODUCTION

Both the minerals to be described below were found during panning operations at Canaan by one of the authors (E.J.S.), who forwarded samples to the N.Z. Geological Survey for identification. When tested in the field with a Geiger counter by Mr D. P. Bullen the mineral grains were found to be appreciably radioactive, and later examination showed them to possess many of the characteristics of metamict minerals (Pabst, 1952; Berman, 1955). The presence of fergusonite at Canaan has already been briefly referred to in Williams *et al.* (1959, p. 5).

FERGUSONITE

Small water-worn grains of fergusonite are common in the gravels of a small stream, known locally as Specimen Creek, about a quarter of a mile north-west of the end of the Canaan road (grid ref. S8/ca. 298712). Besides fergusonite the heavy concentrate shows numerous little cubes of limonite pseudomorphous after pyrite; less frequent grains of ilmenite; and minor gold, zircon, epidote, hornblende, biotite, and garnet.

The fergusonite grains are up to 7 or 8 mm long; many are irregular in shape, but several have a prismatic habit and are more or less square in cross section. On the surface the grains have a very thin layer of dull, dark brownish-grey alteration. No cleavage is visible. The fracture is conchoidal, and the broken surface dark brown with a resinous lustre. Under the microscope the powder is yellow or yellow-brown in colour; the larger fragments are translucent or opaque but the smallest grains and the thin edges of many of the larger ones are transparent. Most of the grains are isotropic although a few have a low, patchy birefringence.

After strong heating for several hours in a platinum crucible over a Meker burner the grains are markedly different in appearance when re-examined under the microscope. In reflected light they are seen to be

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[1] N.Z. Geological Survey, Department of Scientific and Industrial Research, Lower Hutt.

[2] Dominion Laboratory, Department of Scientific and Industrial Research, Lower Hutt.

[3] Canaan, via Motueka, Nelson.

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covered with a dense, "woolly", almost opaque layer, yellowish-green to brownish-green in colour. With maximum illumination in ordinary light the thinner grains prove to consist of a mass of extremely minute doubly-refracting crystallites with low bifringence.

The powder of the unheated mineral is amorphous to X-rays. After strong heating, however, as recommended by Berman (1955, p. 810), well developed X-ray diffraction patterns were produced (Table 1, A). These are close to the patterns for ignited fergusonite given by Berman (1955, pp. 819–20).

TABLE 1—X-ray Diffraction Data for the Heated Powders of Fergusonite (A) and Samarskite (B) from Canaan, North-west Nelson

A		B	
d(Å)	I/I_1	d(Å)	I/I_1
4·04	10	4·03	40
3·13	100	3·60	30
2·965	80	3·23	50
2·75	40	3·13	40
2·65	25	2·97	40
2·53	15	2·925	100
2·455	7	2·81	15
2·165	7	2·765	15
2·015	7	2·655	15
1·905	50	2·52	30
1·86	25	2·455	15
1·76	10	2·34	10
1·65	15	2·18	15
1·63	20	2·06	10
1·57	20	2·02	15
1·51	10	1·915	20
1·48	7	1·875	25
		1·825	10
		1·74	15
		1·715	25
		1·695	20
		1·655	10
		1·635	15
		1·575	15
		1·52	15
		1·44	15

Two samples were analysed spectrographically, and the results are given in Table 2, A and B. The composition, essentially a complex oxide of columbium and yttrium, is comparable with the analyses of columbium-rich fergusonites given by Dana (1944, pp. 759-60).

SAMARSKITE

The samarskite was found as a single large squat grain, 8 mm long, in a panned concentrate at Atkin's Creek, several miles south of the fergusonite locality (grid ref. S8/ca. 260660). Other minerals in the stream concentrate at this locality are magnetite; numerous little plates of ilmenite; many grains up to 3 mm across of rutile and monazite; occasional limonite nodules and pseudomorphs after pyrite; and minor gold, zircon, epidote, and garnet.

The fragment of samarskite appears to be made up of several thin tabular sub-individuals in parallel growth, terminated by fairly well defined dome or pyramid faces (Fig. 1). The outer surface is black except for a little powdery rusty-coloured weathering (Fig. 1). The broken surface is black, with a shining resinous lustre. Fracture is conchoidal, although under the microscope several fragments show a well marked parting. The powder is opaque except in very thin slivers; in these it is translucent, with a brown or light yellow-brown colour. The grains are always isotropic.

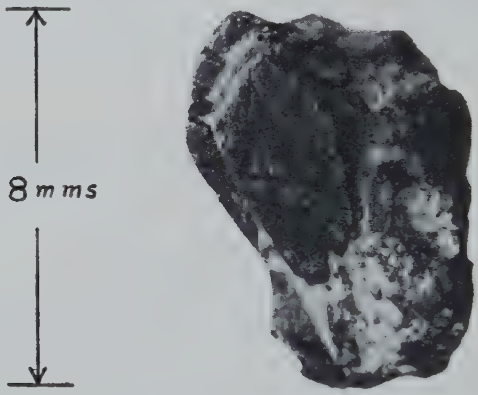

Photo by N. Beatus

FIG. 1—Samarskite grain from Atkins Creek, Canaan, North-west Nelson. The light areas represent superficial rusty-coloured alteration.

After strong heating over a Meker burner many of the fragments are seen under maximum illumination to be changed to a crypto-crystalline mass of tiny, poorly birefringent crystallites.

TABLE 2—Spectrographic Analyses (in wt. %) of Fergusonite (A, B) and Samarskite (C) from Canaan, North-west Nelson

	A	B	C
Columbium …… …… ……	40	40	40
Tantalum …… …… ……	2	2	2
Titanium …… …… ……	1·5	1	2
Zirconium …… …… ……	0·3	0·1	0·15
Yttrium …… …… ……	30	40	5
Ytterbium …… …… ……	4	4	1
Scandium …… …… ……	<0·01	<0·01	1
Thorium …… …… ……	6	8	8
Uranium …… …… ……	10	10	15
Iron …… …… ……	0·5	1	15
Manganese …… …… ……	0·05	0·07	1·5
Silicon …… …… ……	0·5	0·5	0·3
Aluminium …… …… ……	0·15	0·2	0·01
Calcium …… …… ……	0·6	1	0·6
Magnesium …… …… ……	<0·01	<0·01	0·03
Tungsten …… …… ……	1	0·5	<0·05

The powdered mineral is amorphous to X-rays before heating. After ignition, a good X-ray diffraction pattern (Table 1, B) showing satisfactory agreement with the data for samarskite given by Berman (1955, p. 819–20) was produced. The result of the spectrographic analysis of the mineral is given in Table 2, C.

PROVENANCE

Fergusonite and samarskite have been reported from many overseas localities, always from granite pegmatites or in gravels derived from these. Both minerals have been used as a minor source of rare earth elements. So far no pegmatites from which the minerals could have been derived have been found near Specimen and Atkin's creeks, although pegmatites of simple mineralogical composition are known from several places in the Canaan area. Much of the watersheds of the two streams is still under heavy scrub and forest, and further field work in these areas may well show the presence of rare-earth pegmatites associated with the Separation Point granite.

NOTE ON METHODS

The X-ray diffraction patterns were taken on a Norelco unit (North American Philips Co. Inc.) fitted with Geiger-counter diffractometer and using nickel-filtered copper K_α radiation of 1·542 Å wave-length. Intensity values were measured as peak height above background, and expressed as percentages of the strongest line.

For the spectrographic analyses the method used was the iron flux technique, developed at Woolwich (C.C.I. Report 8007, Ministry of Supply, England – restricted) and published by the Institute of Petroleum (Institute of Petroleum, London, Standard Methods IP 122/55 T). The spectrograph available was the Hilger double Littrow, and both quartz and glass optical trains were used. Briefly, the technique is to mix the sample with a large excess (at least 10X) of a flux containing iron. The mixture is pelleted, and excited as cathode in a D.C. arc between copper electrodes. On the processed plate the element lines are visually compared with the iron lines using line-pair equalities previously determined from synthetic mixtures. Accuracy is not high, but for many elements it has been found to be within ± 50% of the content.

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PRELIMINARY SURVEY OF THE HYDROTHERMAL FIELD AT RABAUL, NEW BRITAIN

By F. E. Studt, Geophysics Division, Department of Scientific and Industrial Research, Wellington*

(*Received for publication, 16 December 1960*)

Abstract

Many hot springs are located around the shoreline of the breached caldera in which the township of Rabaul stands. The hydrology and chemical analyses suggest that there is convective circulation of sea water in a zone of subsidence close to two young volcanoes. The total heat flow is not known and there appears to be little thermo-artesian pressure or hot water storage, but it may nevertheless be possible to exploit a part of the hydrothermal field to supply Rabaul's power requirements. Further investigation and test drilling are required before a final assessment of the project can be made.

Introduction

The power requirements of the township of Rabaul, New Britain, are at present supplied by diesel-driven generators, but high generating costs and increasing demand have prompted consideration of the relative merits of hydro-electric and geothermal stations, capable of generating 5 MW initially, with ultimate expansion to 20 MW. With such loads, either of these systems would give cheaper power than diesel fuel, but the nearest suitable hydro-electric project would involve high capital cost and long transmission lines, whereas the capital cost of a geothermal station would be comparatively small, and there are many hot springs within a mile or two of the town. The prospects of successful geothermal exploitation cannot be judged, however, on the information at present available. This paper sets out some conclusions drawn from an examination of the field, made in company with Mr A. C. L. Fooks, Project Engineer, Ministry of Works, Wairakei.

Geological Background

The geology and volcanology of the area have been dealt with by Fisher (1939), whose work led to the establishment of the Volcano Observatory in Rabaul and of routine temperature measurements in hot springs and fumaroles.

Blanche Bay is an elongated caldera on the North Coast of New Britain, measuring about 9 miles by 6 miles and open to the sea in the south-east (Figs. 1 and 2). Rabaul is situated on a narrow strip of land within the caldera wall at the northern end. Also within the wall on the east and west sides are two volcanoes, commonly known as Matupi and Vulcan (Tavurvur and Baluan), which erupted simultaneously in 1878 and again in 1937; Matupi resumed eruption in 1941–2, but now emits only small quantities of steam and gas. Rabalanakaia is a second very young crater on

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*Now Officer in Charge, Information Bureau, D.S.I.R., Wellington.

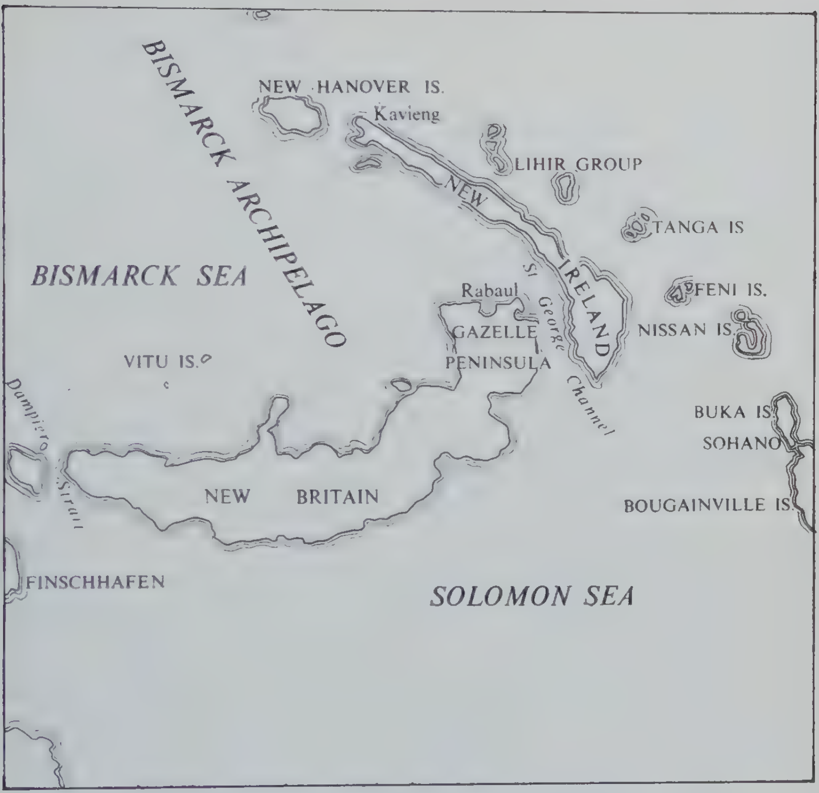

FIG. 1—Locality map of Bismarck Archipelago.

the eastern side of the caldera, but there is no record of its eruption. The Mother and the North and South Daughters are older volcanoes disposed around the eastern caldera rim; they antedated the caldera subsidence.

The older volcanoes are composed of basalt lava and tuff, but the proportion of pyroclastic material has increased with time, and the latest eruptions of Matupi and Vulcan produced mostly andesitic pumice. The northern and western parts of the caldera have been covered with a considerable thickness of pumice, and holes drilled for town water supply in Rabaul pass through 50 ft or so of this material, into an old beach deposit, and thence into basalt. Near Rabalanakaia, the height and steepness of the caldera wall suggest very recent subsidence; here the pumice is not seen, and a basalt flow from Rabalanakaia crater crops out.

HYDROLOGY

The main hot springs are concentrated around the shoreline from Rapindik to Matupi Volcano (Fig. 2), and small steam vents and patches of slightly steaming ground are found between here and the craters of

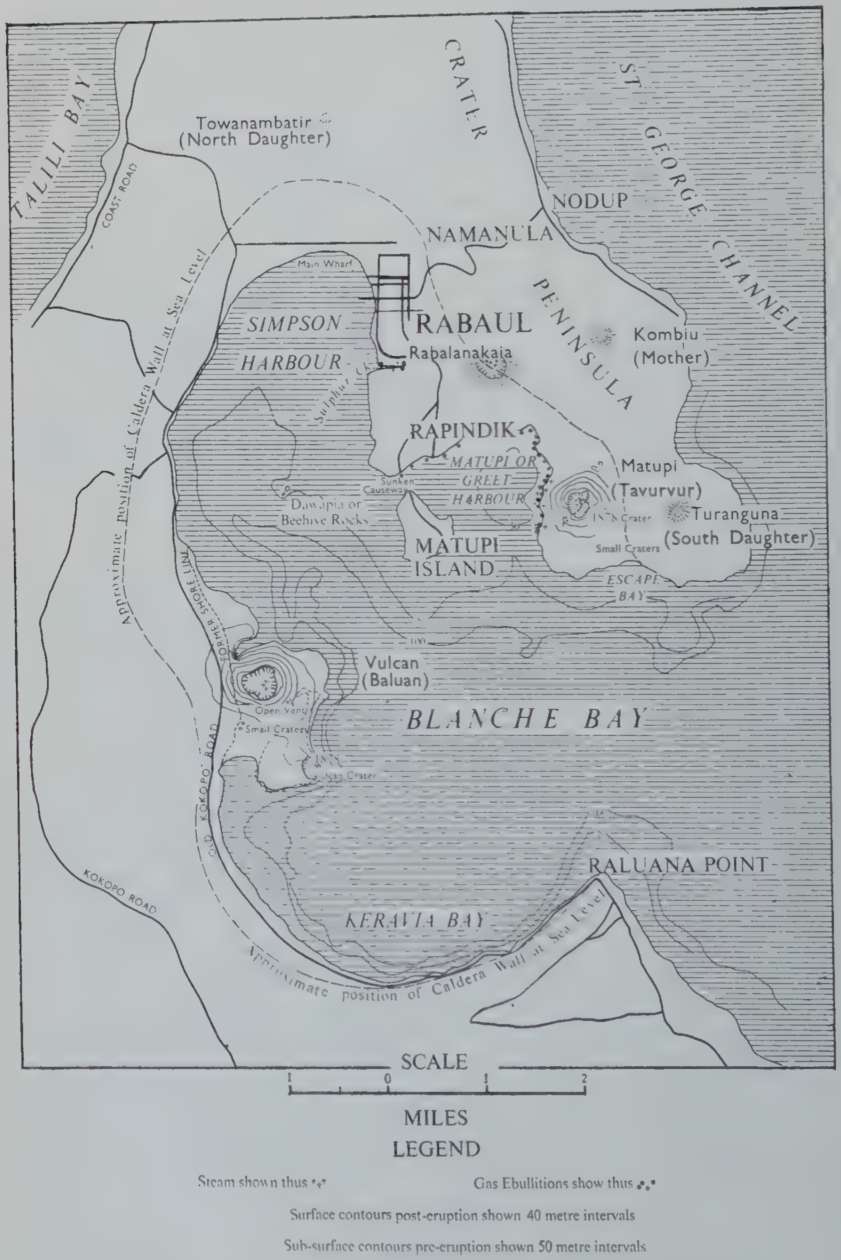

FIG. 2—Blanche Bay, after map drawn by N. H. Fisher (1939). Hydrothermal features shown are those mapped by Fisher, some of which have since disappeared.

Matupi and Rabalanakaia. There are other hot springs at Sulphur Creek and around Vulcan, but only the Matupi-Rapindik area need be considered for purposes of exploitation; the springs here have a history of sustained activity, whereas those around the volcanoes themselves have deteriorated since the 1937 eruptions. The Matupi-Rapindik area also has the greatest heat flow and the highest spring temperatures; it is in fact the only area where spring temperatures close to 100°C are recorded. Superheated fumaroles were reported by Fisher shortly after the 1937 eruptions, but the temperatures declined rapidly in succeeding months; there are still many gently steaming areas, but there are no longer any vents with temperatures above 100°C even in the craters.

The discharge of steam and water from a drillhole depends upon the presence of water at so high a temperature that it will boil upon being drawn towards the surface, that is upon reduction of the pressure by removal of part of the overlying column of water. The most favourable areas are those in which the actual temperatures are close to the saturation temperatures corresponding to the prevailing hydrostatic pressures, and this condition is obviously more likely to be found where the surface temperatures reach 100°C than where they fall short of this figure, as for instance at Sulphur Creek.

The most striking hydrothermal feature is the complete absence of hot springs more than a foot or two above sea level. The springs occur typically along the shoreline between high- and low-water levels, and since the tidal range is only two to four feet, the distribution is extremely limited. Nevertheless, there are many parts of the Matupi-Rapindik shoreline where bubbling and upwelling of hot water can be seen, and elsewhere the sand at the water's edge is uncomfortably hot to the hand only an inch or so below the surface. There may be much unseen seepage into the sea further offshore.

The limited distribution of springs could be due to the presence of a cap rock of some description, so disposed that the hot water escaping around its edge appears only along the shore line. But since steam penetrates to the surface a short distance back from the beach, such a cap could not be very impermeable. A much more likely explanation is that there is insufficient thermo-artesian pressure to raise the hot water far above the cold water table. This implies that there is no great depth of hot water near the coast, and that drillholes in this vicinity would probably pass through hot into colder water below. Such temperature layering is common at the edges of hydrothermal fields, especially where there is a plentiful supply of cold water nearby, as there is here in the sea.

The hot spring distribution strongly suggests that the hot water rises to the water table close to the eastern caldera wall and then percolates seawards. This would put the source of the hot water in the zone of very recent subsidence near Rabalanakaia. The patches of steaming ground in this zone may mark the fractures up which the hot water comes, but they might be no more than local permeable zones, through which the steam rising from the hot water table can escape to the surface. If the source of the hot water is near the caldera wall, then high temperatures must extend to greater depth in this neighbourhood than is indicated near the coast, and consequently the pressure of the hot water must also be greater. Despite this, steam alone reaches the surface inland, so that the hydraulic gradient toward the sea cannot be as steep as the topographical gradient. This is probably due to the high permeability of the near-surface rocks.

The routine measurements made by the staff of the Volcano Observatory show some evidence of fluctuation in a few spring temperatures, which might be due to rainfall effects. The catchment area is very small, and if this correlation were established at many springs, it would be a clear indication that the near-surface volume of hot water cannot be very large. However, most of the measured springs appear to show little temperature fluctuation.

CHEMISTRY

A hot spring (69·5°C) was formerly active at Rapindik, but an earth movement is said to have stopped its flow and a well was sunk to take its place. Bubbling water was encountered at 16 ft, but the temperature measured in the bailed water was only 71°C (Mr A. Q. B. Davis, pers. comm.). Chemical analyses of both these waters show that the sodium chloride content (1882 and 1503 grains per gallon) was close to that of sea water. Certain chemical data for other springs, made available by Professor Baas Becking, also suggest that sea water may contribute a major proportion of the discharge (Cl^- content ranges up to almost 30,000 parts per million).

It is possible, therefore, that there exists a circulation system in which sea water is drawn through the rocks at some depth toward the eastern edge of the caldera. Here it is heated, both by contact with hot rocks and by admixture of magmatic water or steam; it rises, and then percolates back towards the sea at a higher level as already explained. This hypothesis is strengthened by the diametrical disposition of the active volcanoes in the caldera, by their sympathetic eruption and by disturbances reported in the sea along the line joining them (Fisher, 1939, p. 37), all suggesting fractures in the caldera floor. Further evidence comes from reports of expulsion of sea water from explosion craters and from the high sodium chloride content found in the debris thrown out by the volcanoes (Fisher, 1939, pp. 23, 52).

However, there is doubtless some contribution to the hot springs from ground water also, though this may not be great. Further chemical analyses may show more clearly the true proportions of ground water, sea water, and magmatic water or steam. Tritium analyses would also be of value in giving an age, or turnover time for the non-magmatic component, and so indicating the size of the system involved.

A most conspicuous feature, especially on aerial photographs, is the brown discoloration of the waters of Matupi Harbour; this is also seen on the rocks wherever hot water is discharged into the sea. Transport of iron is not a common feature of the New Zealand hydrothermal fields, where magnetite is converted to pyrite in situ in the rocks. This reaction is favoured by alkaline or neutral conditions, whereas the leaching of iron that is taking place at Rabaul indicates acid conditions. This suggests that drillholes would have to contend with acid waters and that corrosion may be troublesome unless heat exchangers are employed. This is seen, too, in the general tendency for high spring temperature to be accompanied by low pH, in contrast to Wairakei. There is a much higher proportion of dissolved solids than is present in most New Zealand waters, which would tend to aggravate corrosion and erosion problems. The Rabaul hot water appears most nearly akin to that on White Island, New Zealand, which is highly acid, and contains up to 10 per cent Cl (Wilson, 1959).

Low silica figures for the Rabaul hot springs (well below equilibrium solubility) suggest that the water has not been in contact with the country rock for any great length of time. This again precludes the existence of any extensive storage of hot water underground.

FURTHER INVESTIGATIONS

Experience in New Zealand has shown that it is worthwhile making geophysical and chemical surveys before drilling, even when the full interpretation is delayed until the results of initial drillholes are available. Such surveys are relatively inexpensive, and if they achieve only a small reduction in the proportion of unproductive drilling, they become profitable. Cost ratios in Rabaul may differ from those in New Zealand, but the potential value of such work, in promoting a better understanding of the hydrothermal system that it is desired to exploit, is such that it cannot well be neglected. The surveys should be devoted to establishing the magnitude and extent of the resources and mapping the geological environment in order to guide the test drilling to follow.

Heat Flow and Temperature Surveys. It is difficult to estimate reliably either the size of the field or the heat flow. The heat flow, of course, is largely hidden in seepage to the sea. Steaming ground and stunted vegetation are common guides to the extent of the New Zealand fields, but in tropical climates the steam is barely visible and the vegetation is acclimatised to high soil temperatures.

The size of the field may be measured by a survey of near-surface temperatures, using either rototherm thermometers or thermocouple probes (Thompson, 1960). Resistivity surveys, designed to map the distribution of hot water at the water table, have also been of use in uniform geological conditions, but the interpretation is complicated by porosity and salinity variations. The extent of hot water seepage through the sea floor could be gauged by extending the temperature survey offshore.

Comparison with the Kawerau field in New Zealand (Studt, 1958), where most of the heat flow occurs in seepage to the Tarawera River, gives the impression that there is ample heat flow at Rabaul for a 5 MW project, but some attempt to assess the heat flow on a quantitative basis is desirable before drilling. An accurate figure would be difficult to obtain because the hot water flows straight into the sea, but an approximation may be possible by impounding a typical section of the beach at low tide and measuring the flow over a low section of the dam. It may, however, be necessary to derive a figure by measuring the hydraulic gradient and the permeability of the rocks, and assuming all the water to be at 100°C.

The overall heat escape as steam is probably considerable, but most of this is on the volcanoes and only a small proportion on the lower slopes close to sea level, so that its contribution to the exploitable resources is doubtful. However, if the project comes to fruition, it is important that the flow of steam, as well as of water, should be measured, because changes in the natural heat escape resulting from exploitation may furnish valuable clues to underground conditions. Various methods have been used for estimating the heat escape; approximate values can be deduced very simply from probe thermometer surveys (Benseman, 1959).

A magnetic survey would probably give valuable assistance. Leaching of iron from the rocks has been mentioned, and this doubtless influences the local magnetic field. A careful magnetic survey should therefore be made to locate those areas in which the field is weakest, on the assumption that these are zones in which leaching is most intense and extends to the greatest depth, i.e., zones of upflow of hot water.

A seismic survey might be able to locate a high-velocity cap rock, but the absence of high velocity would not preclude the existence of a cap.

DRILLING

Although there appears to be an adequate flow of hot water, it is necessary to discover whether adequate temperature and pressure exist, within the range of whatever drills may be used, to give a spontaneous discharge. At present there is no indication of this at all. No stipulation can be made as to the temperature and pressure required, since the best procedure is to discover what is available and then write turbine specifications accordingly.

In the New Zealand hydrothermal fields, the best conditions are invariably found beneath a relatively impermeable layer, which impedes the upward flow of hot water. Such a layer forces the hot water to spread out and displace cold ground water, so that it is more easily tapped; at the same time, it causes a build-up of temperature and pressure beneath it. At Larderello, on the other hand, dry steam is obtained from fractures in an otherwise impermeable formation, from which meteoric water is excluded. In both fields, the essential requirement is an impermeable rock, and this is what should be looked for at Rabaul.

From the known rock types, from the history of subsidence, and from the hydrology, it may be argued that an extensive, very impermeable layer is unlikely to be present. It must be emphasised that a cap rock in a hydrothermal field, unlike those in oil fields, need only be relatively impermeable by comparison with the suroundng rocks; nevertheless, the possibility must be envisaged that there are no such layers within economic drilling depths, that there is little rise in temperature with depth, and little available thermo-artesian pressure.

Under such conditions, it would still be possible, as has been shown in the Belgian Congo (*Overseas Engineer*, 1953) to utilise hot water at 100°c or even less, by flashing and exhausting to vacuum. Even this method, however, would be impracticable without a small head above sea level, and pumping may be necessary to obtain this. A high proportion of dissolved gases would mar the efficiency of this system, and details would be required; more detailed information would also be required of the natural mass and heat flow for such a project, for without a reservoir of hot water under pressure, heavy pumping might draw in cold water through the permeable surface beds. Such information would be relatively easy to obtain, since deep drilling is not required.

It is now accepted policy in New Zealand that, in general, test drilling should be carried to the maximum depth possible with the rigs available. For this there are several reasons: (1) temperature, pressure, and available steam fraction usually increase with depth; (2) even where there is a temperature inversion, it pays to draw from below the maximum temperature horizon, in order that the water which is tapped shall boil in the hole rather than in the rocks – minerals deposited at the flash point can be cleared from the hole, but not from the rocks; (3) there may be more than one aquifer.

Unless a high velocity is recorded by seismic prospecting, however, the chances of finding a relatively impermeable formation do not appear to be good enough to justify the shipping of a drill rig capable of drilling to more than about 1,000 to 1,500 ft. On the other hand, the permeable nature of the rocks will probably require high-capacity pumping, mud-control, and grouting equipment.

Because of the possibility of drilling through hot into colder water near the coast, the initial hole should be well back from the shore, close to the steaming ground at the foot of Rabalanakaia, or as indicated by the results of the magnetic survey. This is the location at which the highest temperatures and pressures are expected, and at the same time it is the location that will give the most useful information on hydraulic gradients. No information is available as to the possibility of obtaining fresh water at this site, and the possibility of using sea water, not only for drilling purposes, but also in the power station, should be considered.

CONCLUSIONS

Temperature measurements show that only the coastal strip between Matupi and Rapindik need be considered for exploitation purposes at the present stage. The source of the hot water is probably near the caldera wall. The limits of the field are not known and should be mapped by a temperature survey. Heat escape appears adequate for a 5 MW project, but it is difficult to estimate; the outflow of hot water along the beach should be measured. Sea water probably plays a large part in the hydrothermal system and the hot water tapped by drillholes may therefore carry a high proportion of dissolved solids. It may also be acid and corrosive, so that heat exchangers may be necessary for exploitation.

There is at present no indication that spontaneous discharge can be obtained, and pumping may be required. Drilling is necessary, and a magnetic survey should be made before this is started to aid in selection of drilling sites. Lack of fresh water may compel the use of sea water for drilling, and possibly in the power house, although condensate would also be available at that stage.

A final verdict on the merits of a geothermal project cannot be given until further investigations have been made The difference in cost of geothermal and hydro-electric stations would justify these investigations.

Geophysical surveys may help in guiding the drilling, and chemical surveys may give a better understanding of the hydrothermal system, but the final proving of the field can come only through test drilling.

ACKNOWLEDGMENTS

The Rabaul survey was made on behalf of the Australian Commonwealth Department of Works, and thanks are due to the Director-General for permission to publish these details.

It is desired to acknowledge, also, the kind hospitality and cooperation of Mr O. C. C. White, Investigating Engineer, and Mr A. Q. B. Davis, Regional Works Officer, Rabaul, both of the Commonwealth Department of Works; also of Mr G. A. Taylor and Mr J. Barry, of the Volcano Observatory, Rabaul.

Valuable discussions were held with Dr A. J. Ellis, of the Dominion Laboratory, D.S.I.R., Wellington, also with Mr A. C. L. Fooks, Project Engineer, Ministry of Works, Wairakei, whom the writer accompanied to Rabaul.

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IRONSAND DEPOSITS OFFSHORE FROM THE WEST COAST, NORTH ISLAND, NEW ZEALAND

By J. C. McDougall. New Zealand Oceanographic Institute, Department of Scientific and Industrial Research, Wellington.

(Received for publication, 8 December 1960)

Abstract

Surface sediment samples have been obtained from the near-shore portion of the shelf off the west coast of the North Island, New Zealand, from depths between 5 and 50 fathoms. The percentage of magnetic ironsand in the sediments has been determined by magnetic separation. The highest percentages (30 per cent by weight) are found close to the shore; at the 50-fathom line – the maximum depth of the samples considered here – ironsand percentage is very low. The concentration of ironsand is ascribed to processes operating in the present and late Pleistocene wave zones.

INTRODUCTION

Although information on the extent and approximate percentages of titaniferous ironsand in the beach and dune sands of the North Island west coast area has been provided by a number of authors (Hutton, 1940, 1945; Mason, 1945; Fleming, 1946; Nicholson and Fyfe, 1958), no sampling of the continental shelf west of these beaches had been undertaken before the present investigation.

During October 1959 and May 1960 two N.Z. Oceanographic Institute cruises were made on M.V. *Viti* to this area, which extends along the coastline from just south of Kaipara Heads to the mouth of the Wanganui River, and seaward to the 50-fathom line, the position of which varies between 6 and 60 miles offshore (Fig. 1).

The objectives of these cruises were threefold: to chart the character and distribution of the surface sediments; to examine the distribution of magnetic ironsand in the area, particularly in the near-shore zone; and to obtain samples of the benthic animals on the shelf for distributional and ecological studies.

In the area, sampling was carried out along eleven east–west lines, 20 miles apart from Latitude 36° 40′ S to 40° 00′ S. On each line sampling was commenced as close as practicable to the shore, and successive stations were then worked at intervals of one mile to a distance of 5 miles offshore, at 2 mile intervals to 20 miles offshore, at 5 mile intervals to 30 miles offshore, and at 10 mile intervals to the shelf edge. Excellent weather and careful navigation enabled sampling to be commenced no further than 2 miles offshore on most lines, the innermost station on any line being ½ mile out. In view of the exposed nature of the coastline this was most satisfactory.

The northern lines from Kaipara to Waitara (Fig. 2) were sampled during October 1959 with the assistance of Messrs N. M. Ridgway, J. S.

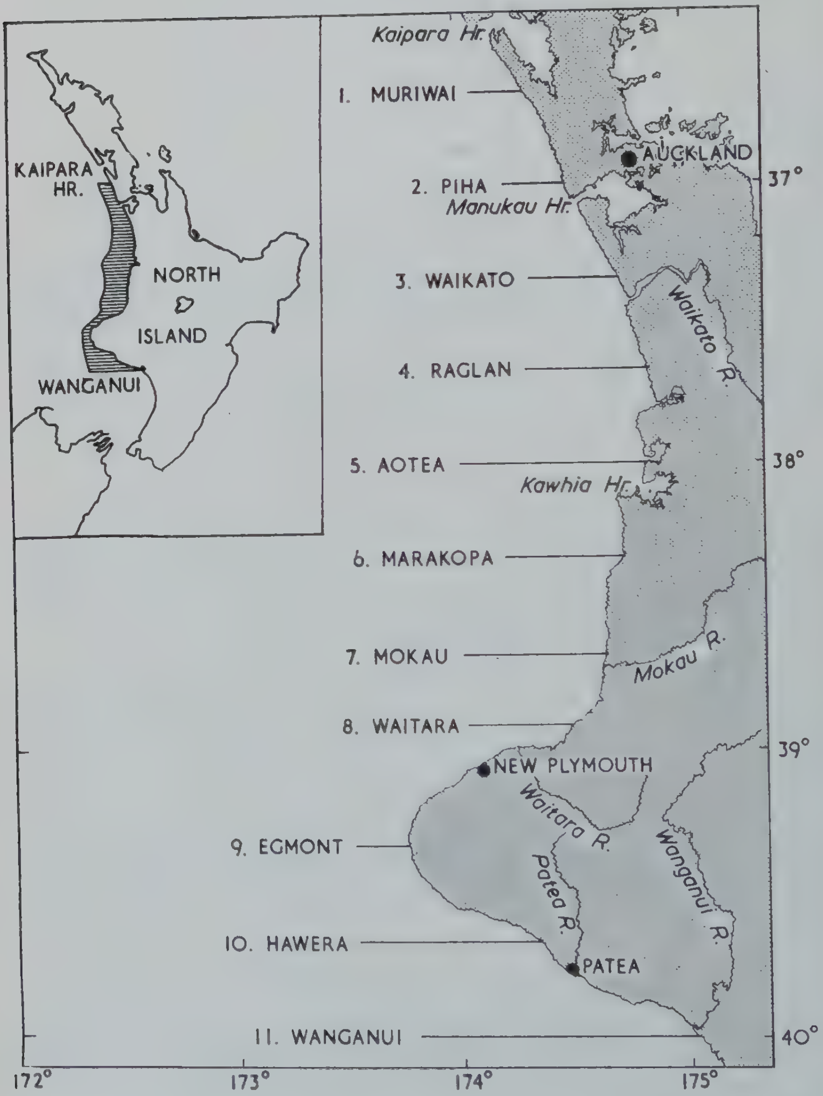

FIG. 1—Locality Chart and Positions of Sampling Lines. The area sampled is shaded. (*Inset*) The seaward boundary is approximately the 50-fathom mark.

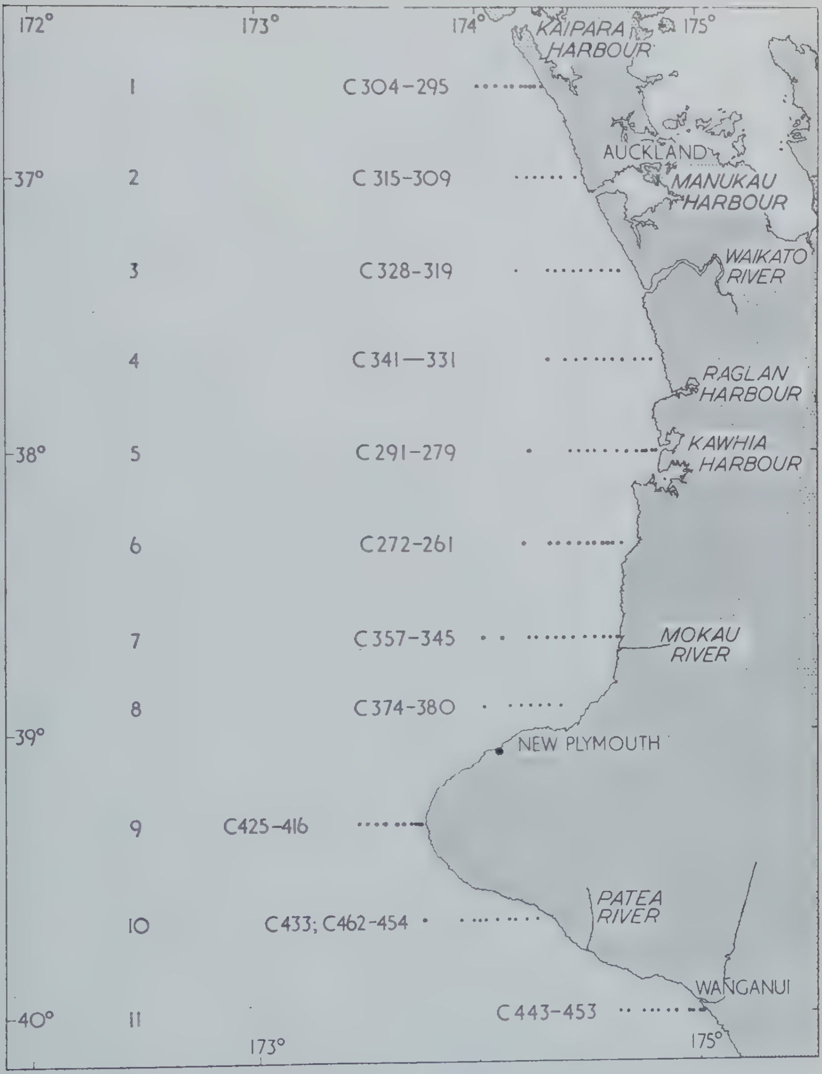

Fig. 2—Station positions.

Bullivant, and K. Tatton, and the southern lines from Egmont to Wanganui in May 1960 with assistance from Messrs N. M. Ridgway, D. J McKnight, and S. C. Watts of the N.Z. Oceanographic Institute staff.

SAMPLING APPARATUS AND PROCEDURE

The sampling gear used from *Viti* consisted of a gravity corer with either a modified Petersen grab or a medium-size orange-peel grab. The stations between Kaipara and Waitara (lines 1 to 8, Fig. 1) were sampled using corer and Petersen grab: those further south between Cape Egmont and Wanganui (lines 9 to 11, Fig. 1) were sampled with corer and orange-peel grab. The corer and either one of the grabs were used as a unit, both being lowered at the same time from the ship, and arranged so that the grab acted as a "trip-weight" allowing the corer a free-fall of approximately 10 feet before entering the bottom sediment (Fig. 3).

The corer barrel consisted of a 3-ft length of 1½in. steampipe fitted with a plastic liner for easy removal of the core. Driving weights of approximately 250 lb were used. Occasionally a 6-ft corer barrel was used, depending on the nature of the sediments, but owing to the extreme difficulty in coring sandy sediments the 3-ft length was usually sufficient.

The modified Hayward orange-peel grab consists of four close-fitting sharp-pointed jaws, taking a roughly hemispherical sample when closed. The model used weighs approximately 100 lb and takes a sample up to one cu. ft. in volume, the maximum penetration being approximately 12 in. The grab has been modified to hang from a trip release which transfers the hauling wire attachment to a closing mechanism when the grab enters the bottom. Sheet metal plates have been added to close over the top of the sampler when the jaws shut and cut down loss of sediment as the grab is retrieved.

The Petersen grab used was a standard pattern sampling 0·1 sq. m. of the bottom, modified by the addition of lead weights on the upper portion of the jaws which had been fitted with several teeth approximately 3 in. long.

The use of these large grabs as trip-weights for the gravity corer minimised station time and permitted a closer cover of stations than would otherwise have been possible if the core and surface sediment samples had been secured separately. The technique likewise made possible the benthic survey, the grab providing a sufficient sample for this preliminary study.

A total of 103 stations was worked, grab samples being obtained at each one and cores at 23 (*see* Appendix). Where coring was difficult, either because of the nature of the sediment, or through rough weather making the gear too dangerous to handle, the corer was dispensed with and a grab sample only was taken. The grab provided a 13-oz oyster-pot sample for grain-size analysis and magnetic separation, and a 4-oz sample, alcohol preserved, for microfaunal investigations: the remainder of the sample being sieved for biological material.

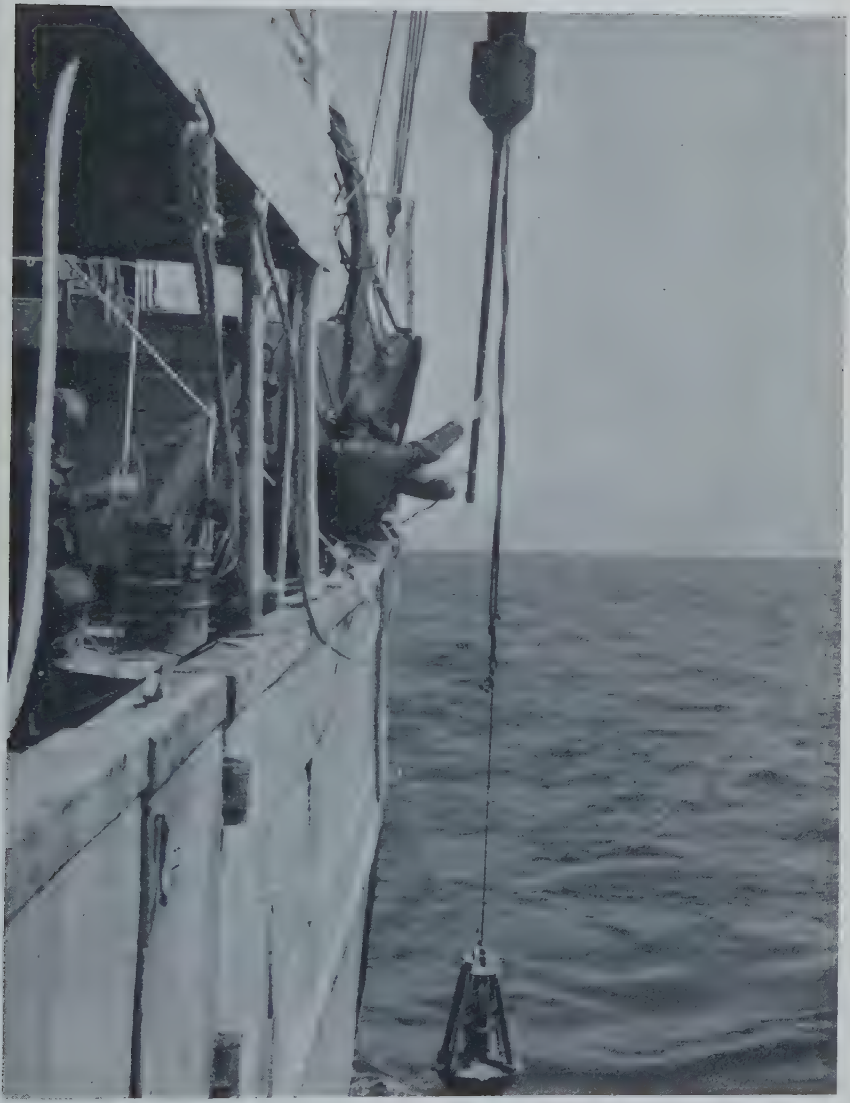

FIG. 3—Recovery of gravity corer with orange-peel grab acting as trip-weight.

LABORATORY TREATMENT OF SAMPLES

A representative sub-sample of approximately 20 grams was set aside from each sample for grain-size analysis. The remainder of the sample was dispersed in a 0·03% NaOH solution, dried by hot plate and passed through a magnetic separator devised by the writer. Where necessary, samples were sieved before separation using a B.S. 16 mesh sieve, to exclude obvious non-magnetic coarse fragments and shell. This minimised the danger of magnetic particles being struck and carried away from the pole-pieces of the separator by non-magnetic fragments during separation.

The magnetic separator consists of three permanent magnets bolted together, with 1½ in. diameter plastic tube 12 in. long supported between the pole-pieces (Fig. 4).

The field strength of the three magnets arranged as in the separator was determined with a Rawson fluxmeter at the Dominion Physical Laboratory, Gracefield, and was found to average 1560 gauss at the poles, and 1830 gauss on the centre line between the poles.

The sample was introduced into the tube by means of a funnel which acted as a hopper. A constant rate of flow was achieved by fixing a piece of stiff card, shaped in the form of an inverted V, in the upper third of the tube, the gap between the apex of the card and the base of the funnel stem being adjusted as required, by simply raising or lowering the funnel. The V-shaped card spread the sample as it fell through the tube and diverted it towards the poles of the magnet. Magnetic particles collected adjacent to the poles, the non-magnetic particles passing through the tube to the container below. On completion, a separate dish was placed tightly against the base of the tube, which was then removed sideways from between the poles of the magnet allowing the magnetic fraction to fall into the dish. This magnetic fraction was reintroduced into the tube and if any minor magnetic particles adhered to the magnets on this second separation, a third separation was made. In general sand-grade samples required no more than the two separations. A small number of samples (5%) required further runs for complete separation; these samples were those consisting principally of fine silt.

Further purification was achieved by placing the magnetic fraction in a shallow petrie dish, covered with a watch glass; a small horseshoe magnet was then placed on the watch glass and manipulated with a circular motion over the sample. This separated any non-magnetic particles which had been mechanically caught up in the magnetic fraction. These remained in the dish, while the magnetic fraction which adhered to the watch glass was removed to another dish. This process was repeated until no further non-magnetic material was evident.

Consistency of Method

Numerous separation procedures were experimented with before adopting that described above. This simple method yielded results which were well within the limits of accuracy required for the present study.

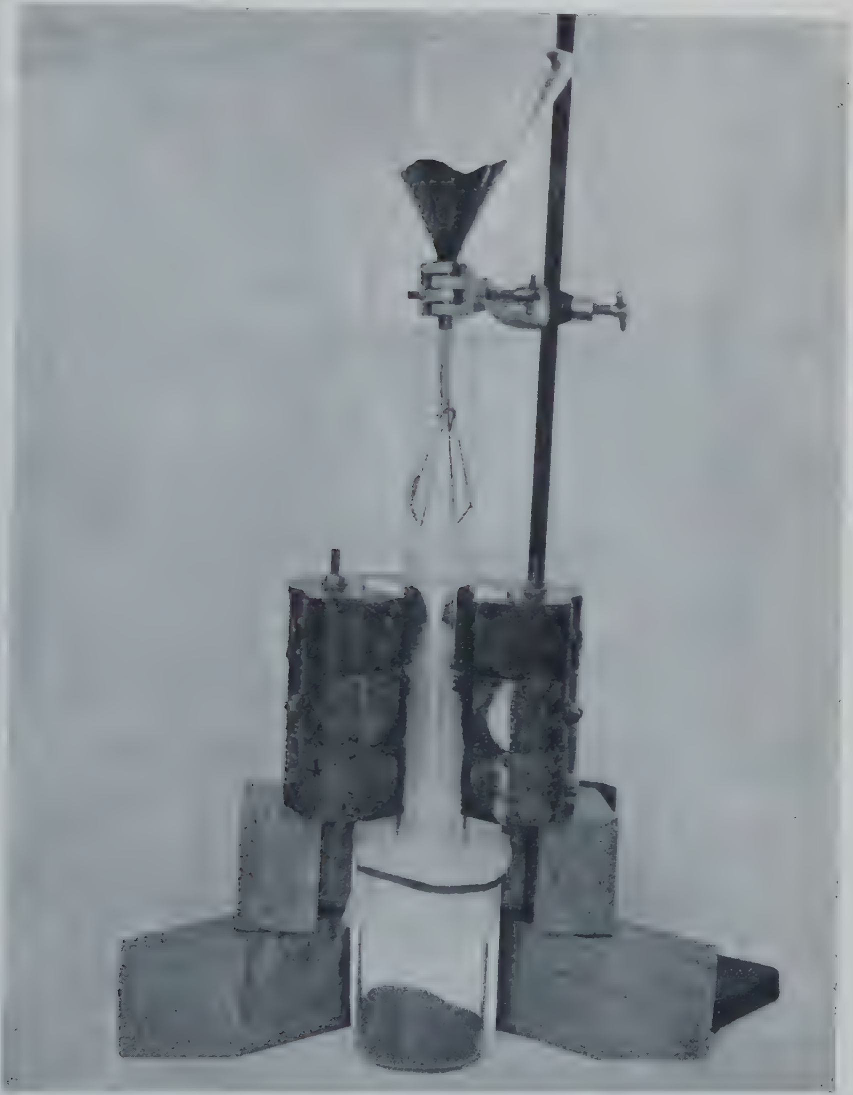

Fig. 4—N.Z.O.I. magnetic separator.

Test runs were made on two samples to determine the consistency of results (Table 1). After each passage through the separator the fractions were recombined and thoroughly mixed. The largest variation from the mean weight in 1·610 g magnetic fraction was 0·026 g.

Calibration of Separator

To determine the performance of the dry separator described here, comparative checks were made using the Davis Tube magnetic separator wet method.

TABLE 1—Results of Repeated Separations of Two Test Samples

	Weight (g)	
	C.309	C.337
Sample before separation	16·851	21.932
Magnetic fractions		
1st separation	1·595	0·381
2nd „	1·623	0·381
3rd „	1·584	0·380
4th „	1·638	0·380
Average	1·610	0·380

Test samples (Table 2) were run through the dry separator as described earlier and the magnetic fraction obtained was passed through a Davis Tube magnetic separator using a water flow of 2·5 litres per minute, a tube angle of 45°, and agitation of 120 strokes per minute. The concentrate fraction was taken out using a magnet current of 0·5 amps and the middlings were obtained by passing the residue at a magnet current of 1·65 amps.

TABLE 2—Comparison of Separation of Magnetic Fraction by N.Z.O.I. Dry Separator (A) and by Davis Tube Magnetic Separator (B)

		A	B
Line	Station	Strongly Magnetic Fraction, % of Total Sample Weight	Concentrate (0·5 amps), % of Weight of the Strongly Magnetic Fraction A
1	C.295	4·9	91·3
1	C.304	3·2	64·7
2	C.309	10·2	93·6
2	C.310	15·9	92·2
3	C.320	16·4	87·4
3	C.327	2·6	96·3
4	C.332	5·7	86·3
4	C.341	1·1	76·3
5	C.279	8·6	90·9
6	C.261	1·5	73·6
6	C.270	2·9	93·1
7	C.345	29·0	88·3
7	C.346	36·1	92·1
8	C.374	2·1	85·9
8	C.380	3·9	78·3
9	C.420	1·1	72·1
10	C.456	12·2	95·6
10	C.459	11·1	94·7
11	C.445	3·1	97·1
11	C.453	1·7	94·4
	Average	8·6	87·2

The maximum percentage by weight removed as a Davis Tube "concentrate" from the magnetic fraction provided by the dry separator was 97·11%, the minimum 64·7%, and the average 87·2%. The "middlings" averaged 2·8% and the "tailings" 10·0% of the magnetic fraction.

The non-magnetic fractions separated from three samples (C.310, C.345, C.456) by the dry separator were also passed through the Davis Tube. The quantities of magnetic material obtained as concentrate (0·5 amp current) were reported as "trace", "negligible", and "negligible", respectively.

RESULTS

Previous geological work has shown that the composition of the black "ironsand" concentrated on the west coast beaches of the North Island is principally titanomagnetite with approximately 9% TiO_2, 0·4% V_2O_3, and 55% metallic iron; accompanying it is a relatively unimportant percentage of titanohaematite (Fyfe, 1952).

Over the whole of the area sampled from *Viti* the ironsand concentration was low (*see* Appendix). The average percentage by weight of magnetic fraction in all the samples was 2·1%. The depth of sediment sampled varied with the sediment grade, being less in the coarser sediments.

Ironsand was, however, present over the whole area and extrapolation of results across the areas between sampling lines can reasonably be made. These results indicate that, for example, in the top 3 in. of sediment over the area, a total of $7{\cdot}4 \times 10^7$ tons of magnetic fraction occur. Analyses have been made to determine the quality of the magnetic fraction. The results of chemical analyses of magnetic fractions from selected stations further separated into concentrate (0·5 amps) and middlings by Davis Tube are given in Table 3. The effective percentage acid-soluble iron in the magnetic fraction is approximately 52·6. Hence, $3{\cdot}2 \times 10^7$ tons of soluble iron occur over this area of roughly 4,000 square miles.

TABLE 3—Percentages of Acid-soluble Fe and Acid-soluble TiO_2 in Selected Samples of "Magnetic Fraction" Removed by Dry Separation and Further Separated in the Davis Tube

Line	Sample Station	0·5 amp Concentrate: Acid-soluble Fe %	0·5 amp Concentrate: Acid Soluble TiO_2 %	1·65 amp Fraction: Acid-soluble Fe %
1	C.295	58·8	8·3	39·6
2	C.310	58·8	8·4	54·8
3	C.320	58·8	8·8	—
4	C.332	55·1	8·5	43·8
5	C.279	47·4	6·9	—
6	C.261	32·2	4·5	23·3
7	C.345	54·6	8·0	47·7
7	C.346	56·4	8·0	47·9
8	C.380	47·0	6·8	—
10	C.456	56·4	7·5	15·6
11	C.453	53·7	7·8	17·8
	Average	52·6	7·5	36·3

The distribution of ironsand on the inner shelf is shown in Figs. 5 and 6. It is evident that there are two preferred groupings of magnetic fraction, at 1–3% and 3–15%.

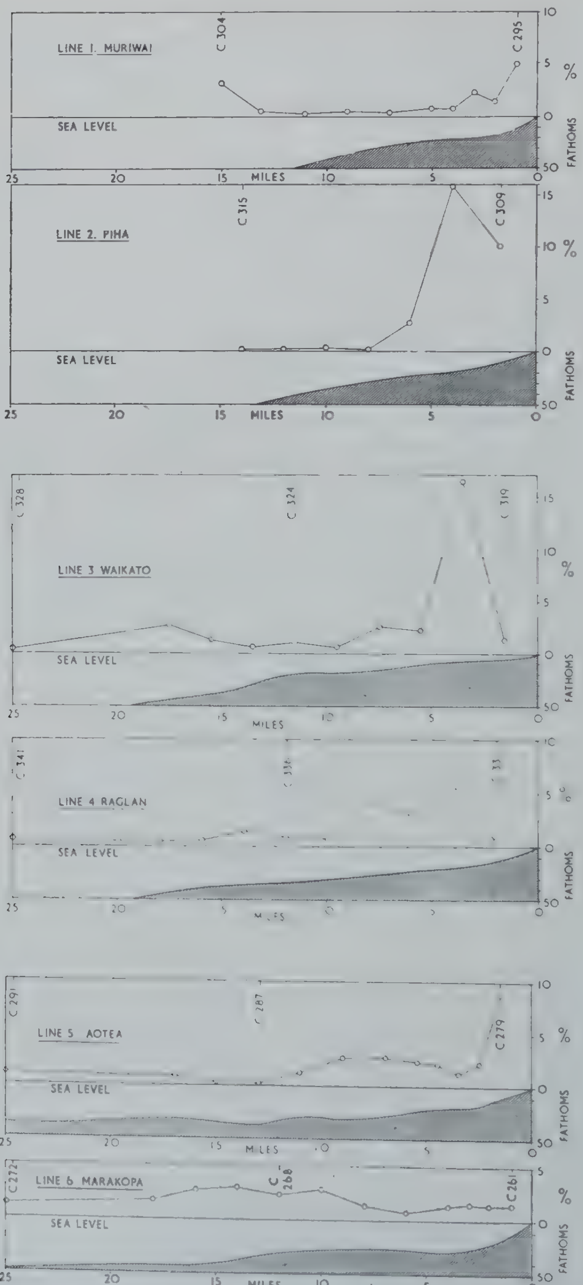

FIG. 5—Variation of percentage magnetic fraction separated by N.Z.O.I. separator, with depth and distance from shore.

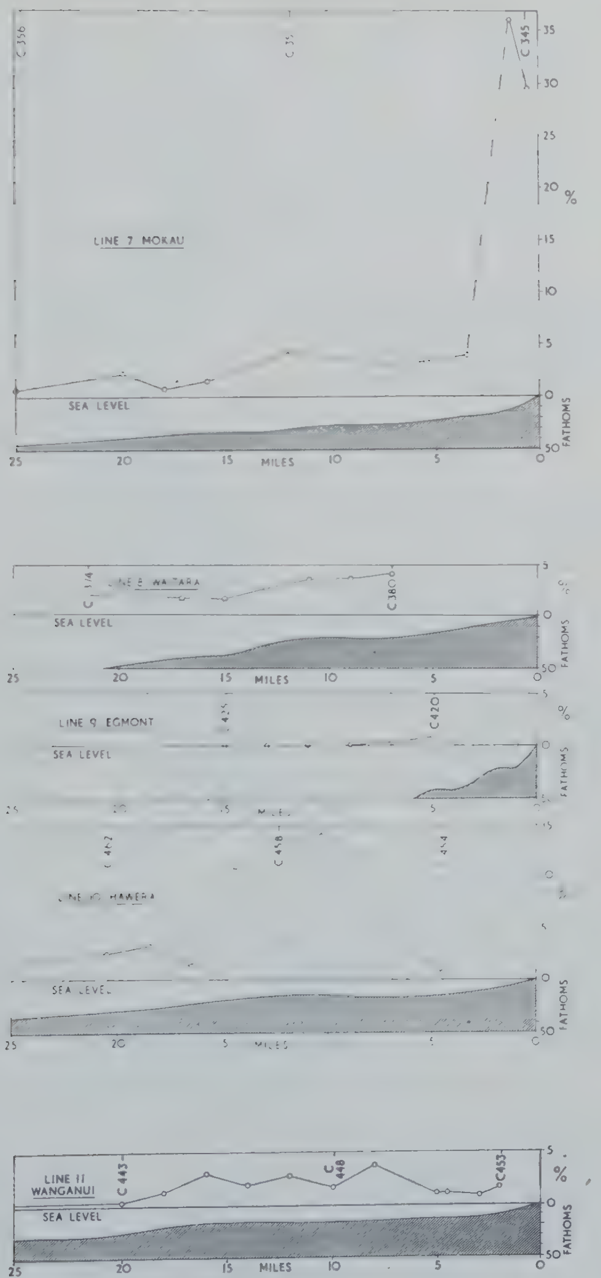

FIG. 5—*continued.*

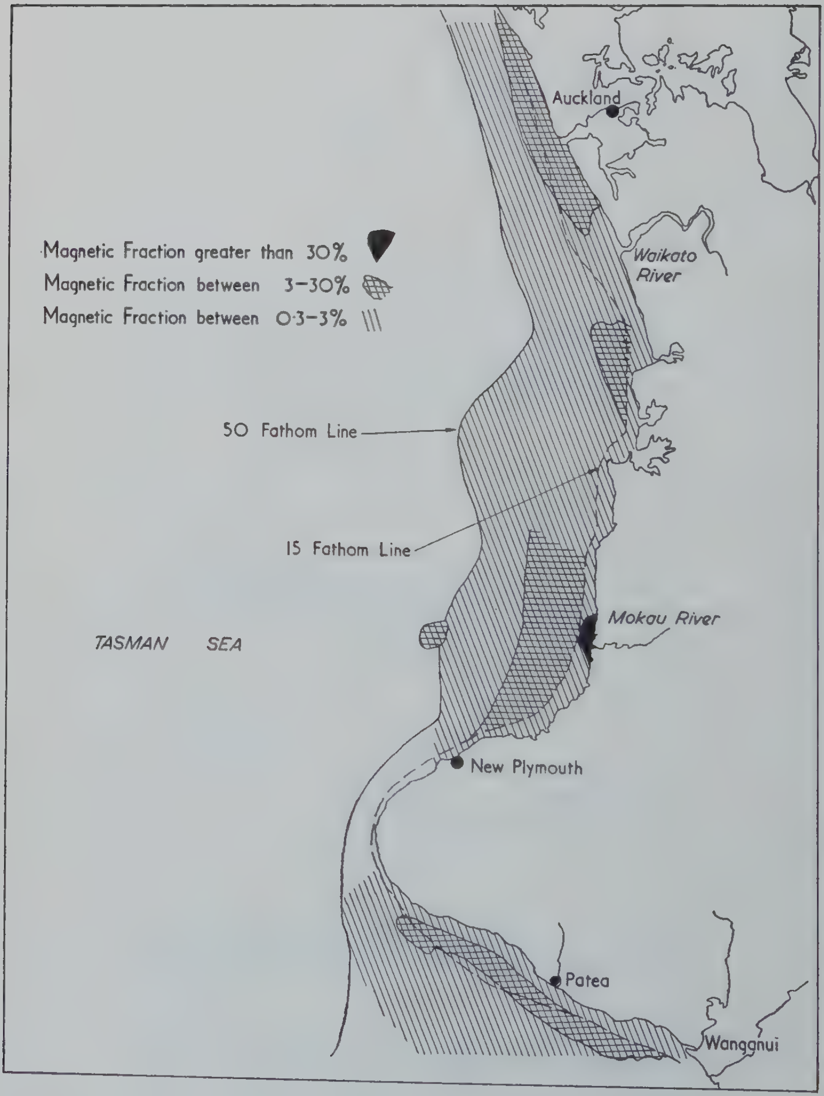
Magnetic Fraction greater than 30%
Magnetic Fraction between 3–30%
Magnetic Fraction between 0·3–3%
Auckland
Waikato River
50 Fathom Line
15 Fathom Line
Mokau River
TASMAN SEA
New Plymouth
Patea
Wanganui

FIG. 6—Regional Distribution of Ironsand Concentration.

The higher concentrations on most sampling lines are confined to the zone within 10 miles of the shore, although samples off Hawera (line 10, Fig. 5) show high concentrations to fifteen miles offshore. Such concentrations are absent at the shore end of some lines but this may well be due to the absence of close inshore samples.

An offshore maximum in concentration occurs in 15 fathoms on eight of the eleven lines sampled. The concentration here ranges from 3 to 36% of magnetic fraction, with an average of approximately 10%. On the other three lines depths as shallow as 15 fathoms were not reached. Indications of a weak maximum in 30 to 40 fathoms occur on five of the eleven lines.

Little variation was evident in a longshore direction though it can be seen from Figs. 5 and 6 that maximum percentages were found off Piha and Waikato Heads, off Mokau (the highest concentration), and off Hawera.

DISCUSSION

The percentages of titanomagnetite in beach and dune sands of the West Coast have been given by Fyfe (1952). The percentage varies from 6 to 80 with an average over sixteen values of approximately 30%.

It is thus evident that with respect to ironsand concentration at or below sea level two maxima occur; one in the beach sands and one at fifteen fathoms approximately. It is tentatively assumed that a process of natural enrichment by gravity is occurring in the present wave or beach zone.

There is no known specific concentration of wave or current energy at the 15-fathom level, and the high ironsand concentration at this depth is better ascribed to similar wave processes operating at a time of Late Glacial low sea-level. Such an assumption must remain in some doubt until more detailed studies of the nearshore zone can be undertaken.

The present investigation does not throw light on the derivation and transport of the ironsand. It is noteworthy that the concentrations offshore from Mt Egmont are relatively low. The enrichment in the beach zone masks any north-south variation in concentration. The ironsand concentrated and immobilised in dunes ashore, perhaps at times of higher Pleistocene sea levels, is many times more concentrated than the deposits normally encountered on the inner part of the shelf to a depth of 50 fathoms and roughly three times as rich as those of the zone centring on the 15-fathom mark.

ACKNOWLEDGMENTS

The writer wishes to thank Messrs W. Shannon and W. Kitt of the Dominion Laboratory for soluble iron and titanium analyses and electromagnetic separations using the Davis Tube separator; Mr G. T. Buck of the Dominion Physical Laboratory electrical workshops for field-strength measurements of the magnets used; Mr S. C. Watts for assistance with mechanical analyses; Mr C. T. T. Webb for draughting of the figures.

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Appendix—Details of Stations Occupied with Percentage of Magnetic Ore at Each Station

Line	Station	Date	Position		Distance From Shore (Nautical Miles)	Depth (Fathoms)	Magnetic Fraction % (By Weight)	Total Weight of Sample Used (to Nearest Gram)	Core Length (In.)
			Lat. S.	Long. E.					
1. Muriwai	C.295	24/10/59	36 39·8	174 17·5	1	12	4·9	398	..
,,	C.296	,,	36 40	174 16·2	2	18	1·3	458	14
,,	C.297	,,	36 40	174 15·0	3	19	2·1	463	..
,,	C.298	,,	36 40	174 13·6	4	22	0·8	483	15
,,	C.299	,,	36 40	174 12·4	5	23½	0·8	529	..
,,	C.300	,,	36 40	174 9·8	7	28	0·4	504	..
,,	C.301	,,	36 40	174 8·0	9	35½	0·5	367	..
,,	C.302	,,	36 40	174 5·0	11	46	0·3	352	30
,,	C.303	,,	36 40	174 2·5	13	56	0·5	269	24
,,	C.304	,,	36 40	173 59·8	15	70½	3·2	425	..
2. Piha	C.309	25/10/59	37 00	174 26·2	1¾	10	10·2	466	..
,,	C.310	,,	37 00	174 23·8	4	19	15·9	525	..
,,	C.311	,,	37 00	174 21·2	6	23	2·6	445	20
,,	C.312	,,	37 00	174 18·8	8	29½	0·2	467	12
,,	C.313	,,	37 00	174 16·3	10	37	0·4	243	19
,,	C.314	,,	37 00	174 14·0	12	43	0·3	332	16
,,	C.315	,,	37 00	174 11·4	14	54	0·2	253	22
3. Waikato	C.319	,,	37 19·6	174 38·5	1½	5	1·2	250	..
,,	C.320	,,	37 19·6	174 36·5	3½	6	16·4	112	..
,,	C.321	,,	37 20·0	174 34·0	5½	11	2·0	407	..
,,	C.322	,,	37 20·0	174 31·6	7½	15	2·3	462	..
,,	C.323	,,	37 20·2	174 28·4	9½	18	0·7	463	..
,,	C.324	,,	37 20	174 26·7	11½	18	1·0	385	..
,,	C.325	,,	37 20	174 24·2	13½	30	0·7	461	..
,,	C.326	,,	37 20	174 21·7	15½	38	1·3	425	..
,,	C.327	,,	37 20	174 19·3	17½	44	2·6	555	14
,,	C.328	,,	37 20	174 11·8	25	65	0·4	334	12

APPENDIX—*continued*

Line	Station	Date	Position Lat. S. °	′	Position Long. E. °	′	Distance From Shore (Nautical Miles)	Depth (Fathoms)	Magnetic Fraction % (By Weight)	Total Weight of Sample Used (to Nearest Grain)	Core Length (In.)
4. Raglan	C.331	26/10/59	37	40	174	47·3	2	14	0·4	390	..
”	C.332	”	37	40	174	44·5	4	20	5·7	317	..
”	C.333	”	37	40	174	42·0	6	22	2·9	379	..
”	C.334	”	37	40	174	39·5	8	27	4·1	456	8
”	C.335	”	37	40	174	37·0	10	30	0·8	460	..
”	C.336	”	37	40	174	34·9	12	34	0·9	422	..
”	C.337	”	37	40	174	32·3	14	35	1·4	368	..
”	C.338	”	37	40	174	29·8	16	40	0·7	452	..
”	C.339	”	37	40	174	27·2	18	46	0·5	343	..
”	C.340	”	37	40	174	24·8	20	53	0·6	257	15
”	C.341	”	37	40	174	19·8	25	67	1·1	389	10
5. Aotea	C.279	23/10/59	38	00	174	47·8	1½	10	8·6	309	..
”	C.280	”	38	00	174	46·8	2½	17½	2·0	397	..
”	C.281	”	38	00	174	45·4	3½	19	1·1	274	..
”	C.282	”	38	00	174	44·0	4½	20½	2·0	375	..
”	C.283	”	38	00	174	42·8	5½	22½	2·2	347	..
”	C.284	”	38	00	174	40·2	7	28½	2·6	434	..
”	C.285	”	38	00	174	37·8	9	32	2·6	459	..
”	C.286	”	38	00	174	35·1	11	30½	1·1	398	..
”	C.287	”	38	00	174	32·5	13	37	0·3	379	..
”	C.288	”	38	00	174	30·3	15	33½	0·4	394	..
”	C.289	”	38	00	174	27·2	17	31½	0·9	402	..
”	C.290	”	38	00	174	25·0	19	33½	0·9	426	8
”	C.291	”	38	00	174	13·0	25	37½	1·1	444	..
6. Marakopa ..	C.261	22/10/59	38	20	174	38·5	1	..	1·5	415	..
” ..	C.262	”	38	19·7	174	37·0	2	..	1·4	349	18
” ..	C.263	”	38	20	174	35·7	3	..	1·7	325	..

,,	C.264	,,	38	19·5	174	34·8	4	28	1·6	345	12
,,	C.265	,,	38	20	174	32·1	6	27	0·9	375	18
,,	C.266	,,	38	20	174	29·8	8	27	1·5	327	..
,,	C.267	,,	38	20	174	27·3	10	29	2·9	424	..
,,	C.268	,,	38	19·7	174	25·0	12	31	2·6	291	..
,,	C.269	,,	38	20	174	22·3	14	38	3·1	451	12
,,	C.270	,,	38	19·8	174	20·0	16	43	2·9	446	..
,,	C.271	,,	38	20	174	17·3	18	44	1·8	438	..
,,	C.272	,,	38	20·3	174	11·8	25	50	1·4	352	12
7. Mokau	C.345	27/10/59	38	40	174	37·5	½	7	29·0	318	..
,,	C.346	,,	38	40	174	36·2	1½	13	36·1	133	..
,,	C.347	,,	38	40	174	33·6	3½	19	4·0	368	..
,,	C.348	,,	38	40	174	31·0	5½	23	3·1	343	..
,,	C.349	,,	38	40	174	28·4	7½	26	3·0	369	..
,,	C.350	,,	38	40	174	25·9	9½	27	3·2	463	..
,,	C.351	,,	38	40	174	23·3	12	30	4·4	471	6
,,	C.352	,,	38	40	174	20·8	14	33	2·7	422	..
,,	C.353	,,	38	40	174	18·3	16	34	1·4	405	..
,,	C.354	,,	38	40	174	15·5	18	36	0·8	435	..
,,	C.355	,,	38	40	174	13·0	20	39	2·1	370	12
,,	C.356	,,	38	40	174	06·6	25	43	0·7	392	..
,,	C.357	,,	38	40	174	00·2	30	52	4·2	564	12
8. Waitara	C.380	28/10/59	38	54	174	21·5	7	20	3·9	132	..
,,	C.379	,,	38	54	174	19·0	9	22	3·7	349	..
,,	C.378	,,	38	54	174	16·5	11	22	3·5	349	..
,,	C.377	,,	38	54	174	14·0	13	27	2·6	313	..
,,	C.376	,,	38	54	174	11·0	15	37	1·6	312	12
,,	C.375	,,	38	54	174	08·5	17	39	1·8	396	..
,,	C.374	,,	38	54	174	02·5	21½	51	2·1	403	..
9. Egmont	C.416	6/5/60	39	20	173	44·5	1	20	Encrusted pebbles and rock		
,,	C.417	,,	39	20	173	43·2	2	22	Small pebbles with mud coating		
,,	C.418	,,	39	20	173	42·0	3	36	Encrusted rock		
,,	C.419	,,	39	20	173	41·0	4	41	Coarse gravel		
,,	C.420	,,	39	20	173	39·0	5	42	1·1	179	..
,,	C.421	,,	39	20	173	37·0	7	59	0·5	71	..

APPENDIX—*continued*

Line	Station	Date	Position				Distance From Shore (Nautical Miles)	Depth (Fathoms)	Magnetic Fraction % (By Weight)	Total Weight of Sample Used (to Nearest Grain)	Core Length (In.)
			Lat. S.		Long. E.						
			°	′	°	′					
9. Egmont	C.422	6/5/60	39	20	173	34·5	9	60	0·2	138	36
,,	C.423	,,	39	20	173	32·0	11	59	0·1	116	30
,,	C.424	,,	39	20	173	29·5	13	61	0·1	113	30
,,	C.425	,,	39	20	173	28·0	15	62	0·1	62	30
10. Hawera	C.454	8/5/60	39	40	174	15·8	4½	13	0·9	440	..
,,	C.455	,,	39	40	174	13·0	6½	14	4·0	493	..
,,	C.456	,,	39	40	174	10·5	8½	14½	12·2	487	..
,,	C.457	,,	39	40	174	08·0	10½	12	14·3	448	..
,,	C.458	,,	39	40	174	05·2	12½	13	3·1	519	..
,,	C.459	,,	39	40	174	02·6	14½	16	11·1	414	..
,,	C.460	,,	39	40	174	00·0	16½	18½	1·5	408	..
,,	C.461	,,	39	40	173	57·2	18½	24	3·7	434	..
,,	C.462	,,	39	40	173	54·5	20½	26	2·8	351	..
,,	C.433	7/5/60	39	40	173	43·5	30	37	1·0	319	24
11. Wanganui	C.453	8/5/60	40	00	175	01·0	2	12	1·7	421	..
,,	C.452	,,	40	00	175	00·0	3	12½	1·0	419	..
,,	C.451	,,	40	00	174	58·0	4½	14	1·4	247	..
,,	C.450	,,	40	00	174	57·0	5	15	1·3	291	..
,,	C.449	,,	40	00	174	54·0	8	16	4·2	415	..
,,	C.448	,,	40	00	174	51·4	10	17	1·8	421	..
,,	C.447	,,	40	00	174	49·0	12	16	3·1	425	..
,,	C.446	,,	40	00	174	46·0	14	16	2·4	466	..
,,	C.445	,,	40	00	174	43·5	16	17½	3·1	595	..
,,	C.444	,,	40	00	174	40·8	18	21	1·4	387	..
,,	C.443	7/5/60	40	00	174	38·0	20	27	0·3	124	..

NEW ZEALAND GEOLOGICAL ABSTRACTS
1958

Compiled by B. W. COLLINS, New Zealand Geological Survey, Department of Scientific and Industrial Research, Christchurch.*

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This tenth annual compilation of abstracts of New Zealand geological publications continues the series undertaken in accordance with the recommendation of the British Commonwealth Specialist Conference on Geology and Mineral Resources (London, 1948). Previous lists were published in *N.Z. J. Sci. Tech.* (Sec. B), and in vols. 1 and 3 of this journal.

Major official publications during 1958 are two regional bulletins of the N.Z. Geological Survey – Grindley on Eglinton Valley (59) and Harrington on Kaitangata Coalfield (64). A petrological bulletin on regional metamorphism in South-east Nelson by Reed (107), and a paleontological bulletin by Squires on the Cretaceous and Tertiary corals of New Zealand (126) were also issued. A new and more detailed geological map of the country was published by the N.Z. Geological Survey (101).

With opportunities for research in the Antarctic afforded by the International Geophysical Year, a few preliminary papers dealing with New Zealand's Ross Dependency appeared (see regional index).

As in recent years, there were many contributions in the fields of Quaternary geology and glaciation (see subject index), some of the more important being: Gage on glaciations of the Waimakariri Valley (52), Gage and Suggate on New Zealand glacial chronology (54), Suggate on late Quaternary deposits of the Christchurch area (132), and a paper on historical variations in glaciers in the Southern Hemisphere (82) published in German by Kolb, who visited this country in 1952. Gage's paper (52) won for its author the McKay Hammer Award of the Geological Society of New Zealand for the most meritorious publication of the year.

Other papers of wide general interest include the following: Cotton's articles on geomorphology and periglacial processes (26, 27, 30); Couper's monograph on British Mesozoic spores and pollen grains (31); Hornibrook's papers on Foraminifera and overseas correlations (70, 71); Kingma on sedimentation and structures in Hawke's Bay (78–81); Lensen on faults (85–90); Mason on intrusions in the Kaikoura Mountains (98); Reed on New Zealand granites and mineralisation (108); Robertson and Reilly on gravity anomalies (114); Smith and Studt on geothermal research and development (123, 130, 131); Steiner on the 1954 Ngauruhoe lava (127); and Suggate on the geology of the Clarence Valley (133).

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The authorship of each abstract is indicated by initials or notes in parentheses. For convenience of reference the publications are numbered serially, and have been broadly indexed by subjects and regions.

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*Now Editor, Information Bureau, Department of Scientific and Industrial Research, Wellington.

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58/1—ANON.: Preliminary Report on the Thickness of Ice in Antarctica. *IGY Bull. 13*: 772–8, 3 figs., in *Trans. Amer. geophys. Un. 39 (4)*: 772–8.

Compiled from material supplied by G. P. Woollard this article includes a brief section on the Ross Ice Shelf (p. 776), which appears to be about 1,000 ft thick and afloat everywhere except around Roosevelt Island and at 83° 30′ S., 163°–169° W. A possible ice thickness of 12,500 ft was measured at 77° 22′ S., 139° 48′ E. in Victoria Land. The average ice thickness in the Antarctic is 8,000 ft or more. (B.W.C.)

58/2—ANON: Quaternary Glaciation. McMurdo Sound Region. *IGY Bull. 14*: 787–9, in *Trans. Amer. geophys. Un. 39 (4)*: 787–9.

From material supplied by T. L. Péwé. Evidence of at least three major Quaternary glaciations, each less extensive than the preceding, was found: 1. Weathered rock deposited on ridges, etc. 2,000 ft above the valley floors; 2. Widespread morainic deposits to an altitude of about 1,000 ft (two major ice-advances); 3. Ice-cored moraines with fresh topography. There has been little change in glacier fronts since 1911. (B.W.C.).

58/3—ANON.: Ross Ice Shelf Deformation Project: 1957–58. *IGY Bull. 14*: 794–8, 3 figs., in *Trans. Amer. geophys. Un. 39 (4)*: 794–8.

From material supplied by J. H. Zumberge. Deformed ice features between Roosevelt Island and the Bay of Whales are due to a form of plastic flow. These include anticlines due to horizontal compression, transverse crevasses due to horizontal tension, and structures resulting from shearing motions. (B.W.C.)

58/4—"AWA-RIKI": Park Valley and Tararua Glaciation. *Tararua (Annual Magazine of the Tararua Tramping Club, Wellington). 12*: 5–10, 2 photos, 2 figs.

A brief historical account of a journey through the Tararua Range in February 1909 by G. L. Adkin and E. S. Lancaster, during which Adkin recognised evidence of Pleistocene glaciation. (G.C.S.)

58/5—BAIN, G. W.: Possible Permian Climatic Zonation and its Application. *Amer. J. Sci. 256 (8)*: 596–600.

The data submitted by F. G. Stehli in support of conclusions on Permian climatic zonation are examined. The boundaries of the distribution areas of selected foraminifera (Fusulines, etc.), drawn to include all occurrences except that in New Zealand, which is unique in other ways than its isolation, delineate a complex undulatory zone, approximating a double sine curve, and the conclusion drawn is that the crust of the earth has shifted relative to the core. The data are replotted as Permian climatic and paleogeographic maps on a sinusoidal chart showing climates and currents when the North Pole was near Samoa. Antarctica split the equatorial drift to give the anomalous New Zealand occurrence of Fusulines. Paucity of fossils in the pelletal part of the Phosphoria Formation is expectable in a cold upwelling current that is the return of the New Zealand warm current.

Enough evidence exists in patterns of major structures, climate, etc., to suggest drift of earth blocks more than twice the movement on the Alpine Fault of New Zealand and the San Andreas rift of California (C.A.F.).

58/6—BECK, A. C.; REED, J. J.; WILLETT, R. W.: Uranium Mineralization in the Hawks Crag Breccia of the Lower Buller Gorge Region, South Island, New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 432–50, 8 figs.

Bedded uraniferous deposits have been discovered in the middle(?) Cretaceous Hawks Crag Breccia formation of the lower Buller Gorge region, and in three areas to the south (Bullock Creek, Waitahu River, and Fox River mouth). The characteristic feature in all the areas is the restriction of the mineralisation to the arkosic facies of the Hawks Crag Breccia.

On the north side of the Buller Gorge, at least ten uraniferous horizons are known, ranging in width from a few inches to several feet. Within each horizon the mineralisation is patchy. The main primary uranium mineral is coffinite which has been introduced along with pyrite, carbonate (largely ferroan dolomite), and red hematite staining of the clastic feldspar. Secondary uranium minerals are generally inconspicuous. The deposits are considered to result from low-temperature mineralisation by epigenetic solutions, but it is still uncertain whether the uranium originated from dispersed sources in the arkosic sediments or was introduced in hypogene solutions from lamprophyres and porphyries.

A comparison is made between mineralisation in the Buller Gorge and on the Colorado Plateau. (Authors' abstract.)

58/7—BELIN, R. E.: A Gamma Radioactivity Survey of Some of the Geothermal Areas of the North Island of New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 156–65, 3 figs.

In a preliminary survey of gamma radioactivity of some geothermal areas in the North Island of New Zealand a wide variation in the radioactivities of soils, pools, and sinters was found between separate thermal areas, particularly between sulphate and chloride areas. In the Wairoa area the average radioactivity of hot pools with no overflow was greater than that for hot springs.

In some hot pools, the variation of gamma radioactivity with depth showed the presence of comparatively active ledges. Sinter deposits around these pools were more radioactive than nearby soils.

It is concluded that the radioactivity observed in the pools is controlled by the physical and chemical characteristics of the pools and not by the water entering from depth. (Author's abstract.)

58/8—BELL, R. E.: Dendrochronology. *N.Z. Sci. Rev. 16 (1–2)*: 13–17.

Tree-ring work in New Zealand will be extremely difficult. The ring records are difficult to read; the matter of false rings is a very troublesome factor; the totara, much used by the Maori, is prone to lack of uniformity so that by collecting different radii different records are obtained from a single tree; and in the four areas studied, only in Auckland were the results consistent for the area. None of the specimens from Taranaki showed similar ring patterns on separate specimens, and this was also true for the Banks Peninsula area and Southern Otago. The possibility of tree-ring dating exists for the Auckland area on the basis of long master charts for kauri and for totara supplemented by white pine. (W.F.H.)

58/9—BLAKEMORE, L. C.; SWINDALE, L. D.: Chemistry and Clay Mineralogy of a Soil Sample from Antarctica. (Letter to editor.) *Nature Lond. 182 (4627)*: 47–8, 1 fig.

Soil collected from Scott Base, McMurdo Sound, contained less than 1% clay and had a high pH due to calcium carbonate as fine shell fragments. The clay minerals present indicate that physical weathering was predominant with chemical weathering negligible. The presence of water-soluble salts shows that movement of water through the soil has been very small. (B.W.C.)

58/10—BRAMLETTE, M. N. Significance of Coccolithophorids in Calcium-Carbonate Deposition. *Bull. geol. Soc. Amer. 69 (1)*: 121–6.

Coccolithophorids are minute biflagellate Protista usually classed as algae, their skeletal material consisting of a number of coccoliths near the surface of a globular body of protoplasm.

Studies of stratigraphic distribution of coccolithophorids indicate that these neglected fossils may be useful in correlation and age assignments. Their vertical ranges seem comparable with other fossils such as Foraminifera. A peculiar and easily identified form, described by Deflandre from the upper Eocene of New Zealand, has now been found in the upper Eocene only of such widely separated regions as Australia, Trinidad, Alabama, and France.

The relative importance of coccolithophorids, Foraminifera, and other constituents in Cretaceous to Recent calcareous oozes and chalks is discussed, and it is concluded that coccolithophorids have had a significant role in the geochemical cycle and balance of calcium carbonate in the ocean basins. (C.A.F.)

58/11—BRODIE, J. W.: Structural Significance of Sea-floor Features around New Zealand. *Geol. Rundsch. 47 (2)*: 662–7, 2 figs.

The oceanic highs and deeps around New Zealand exhibit a marked linearity and fall into three groups whose features trend NW–SE, E–W, and NNE–SSW. These groups are recognised as structural provinces – the North-western, Chatham, and Kermadec Provinces respectively, with both age and geographic differences.

The New Zealand land mass occupies a position at the meeting of the three structural trends and the relief is taken to be a function of this conjunction. Reference is made to the continuation ashore of a number of oceanic structures.

No signs of late structural activity along trends referable to the North-western and Chatham provinces have been observed in New Zealand, and the submarine relief in these provinces could be of pre-Tertiary age. Active movement on the Kermadec province trend has taken place up to Recent time, and the submarine features of this region are considerably younger.

A bathymetric chart of the sea-floor around New Zealand with isobaths at 250 fathom intervals accompanies the paper. (Author's abstract extended.)

BRODIE, J. W.: *See also* 58/66.

58/12—BRODIE, J. W.; HATHERTON, T.: The Morphology of Kermadec and Hikurangi Trenches. *Deep-Sea Research 5 (1)*: 18–28, 8 figs.

The Kermadec Trench extends 700 miles from 26° S towards New Zealand. Its steep sides with major benches, narrow floor and greater depth separate the Kermadec Trench from the slightly offset, broader and shallower Hikurangi Trench off the east coast of New Zealand. Hikurangi Trench has small-scale benching along its axial depression.

Benched sides are also found in Tonga Trench and in other Pacific trenches. The benches are ascribed to superficial normal faulting on the flanks of a major deep-seated crustal depression.

New soundings obtained in the S.W. Pacific by explosion sounding equipment are discussed and the instrumentation described.

New names, Hikurangi Trench, Colville Ridge, and Havre Trough are proposed for bathymetric features not previously clearly defined. (Authors' abstract.)

58/13—BROWN, D. A.: The Relative Merits of the Class Names "Polyzoa" and "Bryozoa". *Bull. zool. Nomencl., 15 (16–17)*: 540–2.

Concludes that J. Vaughan Thompson's term "Polyzoa" should be universally adopted in preference to C. G. Ehrenberg's "Bryozoa", not only because of its clear priority in time, but also as a tribute to a scientific worker of great merit. (B.W.C.)

58/14—BROWNE, W. R.: Professor W. N. Benson, F.R.S. (Obituary). *Aust. J. Sci. 20 (6)*: 175–6.

A tribute to "one of the most distinguished geologists of our time" – "a very successful, inspiring and well-beloved teacher", but "it is chiefly for his research that he will be remembered". No bibliography. *See also* 58/69. (B.W.C.)

58/15—BULLEN, K. E.: Aspects of Research on the Earth's Interior, with Special Reference to Seismology. *Aust. J. Sci. 21 (4)*: 93–9.

Mainly a general historical account from the time of Newton. Includes a brief survey of seismological work in Australia and New Zealand, and of the author's research on travel-times and the earth's internal density variation and constitution. (B.W.C.)

58/16—BURT, E. D.; NEYLAND, P. A.: Properties of Some Foundry Sands Found in the Auckland Area. *N.Z. Engng. 13 (6)*: 217–8.

The desirable properties of sands for various moulding purposes are summarised. Chemical and mechanical analyses of sands from 13 localities are given. No very suitable natural sand occurs in the district, but several are of use for synthetic mixtures. *See* 57/17. (B.W.C.)

58/17—BURT, E. D.; NEYLAND, P. A : The Properties of Some Foundry Sands Found in the Auckland Area. *N.Z. Dep. sci. industr. Res., Inf. Ser. 20.* 19 pp., 7 figs. See preceding abstract 58/16.

58/18—CAREY, S. WARREN: A Tectonic Approach to Continental Drift. In "Continental Drift: a Symposium." Dept Geol. Univ. Tasmania. pp. 177–355.

New Zealand is discussed in an analysis of world structure applying the author's orocline hypothesis. The swing in strike of the fold axes through almost a right-angle between the Southern Alps and the North Auckland peninsula constitutes the New Zealand Orocline. The Alpine Fault, which has sufficient magnitude to be called a megashear, is not well known in the North Island but can be extended into a major thrust fault zone flanking the eastern side of the greywacke belt from Palliser Bay to the Bay of Plenty. The picture which results when the displacement of the megashear is reversed is the final confirmation of the identification of the megashear in the North Island. The offset of equivalent structures by slip along the megashear and attenuation drag adjacent to it, amounts to about 500 km. To reconstruct the paleogeography this displacement must be reversed. The next step is to unwind the New Zealand Orocline which closes the sphenochasm between the Gisborne and Auckland peninsulas, also closing the Fiji Rhombochasm, closing the Tonga, Fiji and New Caledonia Orotaths, and unwinding the Fiji Orocline, for all these movements are inter-related. After these movements are reversed, the belt of older Paleozoic rocks strikes along the New Zealand submarine platform to connect with the Oriomo-Aru Bomberai ridge of New Guinea. The platform between Stewart Island and Campbell Island is seen to be merely the ridge of Paleozoic rocks offset by the New Zealand Megashear. The Mesozoic geosyncline in greywacke facies now runs from Otago to North Auckland, then swings along the New Caledonian Ridge to New Guinea. The reversal of the New Zealand Megashear swings the New Zealand ridge towards the Australian shelf and goes a long way towards closing the East Australian Rhomobchasm. (C.A.F.)

58/19—CARR, R. M.; FYFE, W. S.: Some Observations on the Crystallization of Amorphous Silica. *Amer. Mineral. 43 (9–10)*: 908–16, 6 figs.

Experiments have been carried out to determine the effect of pressure and temperature on the rate of formation of quartz from silicic acid. The rate is much more sensitive to pressure than temperature and this is discussed in terms of possible mechanisms. Cristobalite and silica-K appear as intermediate phases before quartz is formed in appreciable quantity. In this system increasing pressure favours the attainment of equilibrium more than increasing temperature. (Authors' abstract.)

58/20—CARTER, A. N.: Pelagic Foraminifera in the Tertiary of Victoria. *Geol. Mag. 95 (4)*: 297–304.

A sequence of 11 faunal units based on pelagic foraminifera is recognised, 10 of the 13 events (mainly first appearances) embodied therein also occurring in the same order in New Zealand. (B.W.C.)

58/21—CHAPMAN, V. J.; RONALDSON, J. W.: The Mangrove and Salt-Marsh Flats of the Auckland Isthmus. *N.Z. Dep. sci. industr. Res. Bull. 125*. 79 pp, 48 figs.

The section "Geology of Mangrove Swamps and Salt Marshes" (pp. 38–42, 5 figs) and following pages (43–8) contain records of shallow bores providing evidence of buried peat and blue mud deposits, indicating past fluctuations of sea level. Radiocarbon analysis shows the peat to be more than 20,000 years old, and since it appears to underlie the deposits of a 40 ft terrace it may well be older than the Main Monasterian transgression (about 150,000 years). On p. 46 is a table summarising the late Pleistocene and Recent geological history of the Pollen Island area, including movements of sea level. Water-table movements during the tidal cycle, and the permeability of the deposits, are also discussed. (B.W.C.)

58/22—COLLINS, B. W.: New Zealand Geological Abstracts 1956: *N.Z. J. Geol. Geophys. 1 (2)*: 395–418.

Abstracts of 112 publications issued in 1956 with subject and regional indexes. (B.W.C.)

58/23—COLLINS, B. W.: Geology Down Under: Earth Sciences at the Antipodes. *GeoTimes 3 (1)*: 12–4.

Brief historical account with mention of research topics of current interest and recent formation of the Geological Society of New Zealand. (B.W.C.)

58/24—COOMBS, D. S.: Zeolitized Tuffs from the Kuttung Glacial Beds near Seaham, New South Wales. *Aust. J. Sci. 21 (1)*: 18–9.

The specimens illustrate both the formation of delicately graded varve-like laminae in fine-grained volcanic ash, and the replacement of volcanic glass by zeolites. (B.W.C.)

CORNES, J. J. S.: *See* 58/103.

58/25—COTTON, C. A.: Evidence of Late Pliocene Warmth in New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 470–3, 2 figs.

The theory of late Pliocene warmth is of some importance in explanation of Southland pedimentation and also of the deep weathering of greywackes at Wellington, where the K Surface, though of late date, may, like the "peneplains" of Tertiary ages in Europe, have been planed in a warm-humid or "tropical" climate. (Author's abstract.)

58/26—COTTON, C. A.: Dissection and Redissection of the Wellington Landscape. *Trans. roy. Soc. N.Z. 85 (3)*: 409–25, 4 pls, 2 figs.

In the development of the Wellington landscape feral (unsubdued) redissection has outpaced cryergic (periglacial) subjugation. Under the primitive forest, dissection and insequent development have taken place rapidly, because the greywacke terrain is shattered and decayed to a great depth. A landscape largely of fine-textured mature dissection has developed as a sequel to mid-Pleistocene deformation of a previously-planed land surface.

The effects of cryergic processes in subduing a landscape and coarsening the texture of dissection are discussed, and Wellington landforms are compared and contrasted with those of Europe where periglacial processes dominated.

Some late Pleistocene erosion forms at Wellington, such as rounded summits, redissected slopes, and fossil gullies are discussed. (B.W.C., mainly from author's abstract.)

58/27—COTTON, C. A.: Alternating Pleistocene Morphogenetic Systems. *Geol. Mag. 95 (2)*: 125–36, 1 pl.

A characteristic finely-dissected landscape relief prevalent in some middle-latitude regions is in strong contrast with smoothed coarse-textured, whale-backed, relatively featureless relief in others, notably north-western Europe. This latter is believed to be relict from the periglacial regimes of Pleistocene ice ages. In New Zealand the former landscape type is typically developed, although there has also been quite strong "periglaciation". (From author's abstract.)

COTTON, C. A.: The Rim of the Pacific. *Geogr. J. 124 (2)*: 223–31.

Some tectonic and volcanic features of the Pacific area are discussed with emphasis on the periphery of the deep ocean basin. The resemblance between the New Zealand and Californian sectors of the rim, at opposite ends of a Pacific diameter nearly 7,000 miles long, is very striking. Great transcurrent faults occur in both areas, and the geological history has been similar. (B.W.C.)

58/29—COTTON, C. A.: Eustatic River Terracing Complicated by Seaward Flexure. *Trans. Edinb. geol. Soc. 17 (2)*: 165–78, 4 figs.

Discusses the origin of river terraces in coastal Catalonia, Spain. (B.W.C.)

58/30—COTTON, C. A.: Fine-Textured Erosional Relief in New Zealand. *Z. Geomorph. 2 (3)*: 187–210, 6 photos., 6 figs.

Relief of fine texture due to sculpture by streams is characteristic of New Zealand. The resulting landscapes closely resemble those of many forested tropical regions, suggesting that identical processes have been in operation during their formation. The dissection of tectonic slopes in the Wellington district is discussed in detail with emphasis on its fast tempo. New Zealand landscapes are contrasted with the more subdued relief and coarser texture in western Europe and eastern North America. In post-glacial times consequent streams have redissected slopes smoothed by soliflual debris during periglacial ages. (B.W.C.)

58/31—COUPER, R. A.: British Mesozoic Microspores and Pollen Grains. A Systematic and Stratigraphic Study. *Palaeontographica B 103 (4–6)*: 75–179, 17 pls., 11 figs.

This monograph presents detailed results of a study of spores and pollen grains from British Jurassic and Lower Cretaceous sediments carried out while the author was a New Zealand National Research Fellow at the Sedgwick Museum, Cambridge. Includes comparisons with forms described from New Zealand. (B.W.C.)

58/32—COWIE, J. D.; SMITH, B. A. J.: Soils and Agriculture of Oroua Downs, Taikorea, and Glen Oroua Districts, Manawatu County. *N.Z. Dep. sci. industr. Res. Soil. Bur. Bull. 16.* 56 pp, 27 figs., 2 maps.

The parent materials of soils in the area studied are described (pp. 7–12). They comprise dune sands (probably of two ages and showing a marked ESE trend) together with minor alluvial sand and clay of both river flats and terraces. The younger complex of unconsolidated dunes is inferred to date from about 1,700 years ago; the more widespread older complex of consolidated dunes, separated from the younger by distinct boundaries, is inferred to date from a little less than 3,000 years. (D.K.)

58/33—CROLL, W. G.: The New Zealand Geological Survey Antarctic Expedition, 1957–58. *N.Z. alpine J. 17 (45)*: 293–302, 4 photos, map.

Though mostly consisting of a narrative of the expedition with details of the party, equipment, and routes followed, this account includes brief mention of rock types and glacial features. (B.W.C.)

58/34—CROMPTON, R. R.: Significance of Amphibole Paragenesis in the Bidwell Bar Region, California. *Amer. Mineral., 43 (9–10)*: 890–907.

Contrasts formation of amphiboles in the Otago schist belt with those of California. Contains an analysis by C. O. Hutton of actinolite from chlorite schist of Chl 3 subzone collected near Jessie Peak, Mid-Wakatipu Survey District, Western Otago. (J.J.R.)

58/35—CROSBY, L. H.; WOOD, E. J. F.: Studies on Australian and New Zealand Diatoms. 1 – Planktonic and Allied Species. *Trans roy. Soc. N.Z. 85 (4)*: 483–530, 9 pls., 1 fig.

Describes and illustrates 135 species of plankton diatoms recorded from Australia and New Zealand waters, including records from the Tertiary of Oamaru originally made by Grove and Sturt in 1886–7. (C.A.F.)

58/36—DAWSON, E. W.: Rediscoveries of the New Zealand Subfossil Birds Named by H. O. Forbes. *Ibis, 100*: 232–7.

Type specimens of most of Forbes's species of New Zealand subfossil birds have been rediscovered in the British Museum (Natural History). The following are discussed (with suggested synonymy):

> *Chenopsis sumnerensis* Forbes (= *Cygnus chathamica* Oliver), *Circus teauteensis* Forbes (= *C. eylesi* Scarlett), *Cnemiornis calcitrans* Owen (= *Cereopsis novaezealandiae* Forbes), *Cnemiornis gracilis* Forbes (= *gracilis* Oliver), *Biziura lautouri* Forbes, *Megalapteryx* Haast (= *Palaeocasuarius* Forbes), *Palaeolimnas chathamensis* Forbes, *Palaeocorax moriorum* Forbes, and *Coenoeorypha chathamica* Forbes. (C.A.F.)

58/37—DAWSON, E. W., 1958: Advances in the Knowledge of the Small Sub-fossil Birds of New Zealand, and their Biogeographical Significance. (Abstract.) *XVth Internat. Congress Zool. Soc. V., paper 22.* 2 pp.

Abstract mentioning present status of the subject, the ecological significance of some geologically young fossil birds, and relation of bird remains to archeological stratigraphy, and *Paryphanta* land snail distribution. (C.A.F.)

58/38—EIBY, G. A.: Origin of Tektites. (Letter to editor.) *Nature, Lond. 182 (4645)*: 1298.

Draws attention to the "plastic sweeping" theory of origin suggested by Hardcastle in *N.Z. J. Sci. Tech.* in 1926, but points out that this theory fails to account for the observed distribution of tektites, which is better explained by the "lunar impactite" theory. (B.W.C.)

58/39, 40—EIBY, G. A.: This Earth of Ours. (The International Geophysical Year.) Part 1. [*N.Z.*] *Post-Primary School Bull. 11 (9)*, 36 pp., figs. Part 2. *Ibid. 11 (10)*, 36 pp., figs.

These bulletins, published by the N.Z. Education Department, provide a background to the geophysical research recently conducted throughout the world. In Part 1 an introduction (the International Geophysical Year) is followed by sections on the earth, and the pull of the earth (gravity). Part 2 consists of sections on the earth's surface (ocean depths and mountain ranges), its waters (tides, currents, waves), and its interior (including earthquakes, crustal layers, and geophysical prospecting). (B.W.C.)

58/41—EIBY, G. A.: The Structure of New Zealand from Seismic Evidence. *Geol. Rundsch. 47 (2)*: 647–62, 7 figs.

The New Zealand region is characterised by a crust 20–25 km in thickness, and a sub-crust extending to at least 37 km. These are separated by a transition layer extending from the base of the crust to a depth of about 100 km. The crust is divided into blocks by steeply dipping faults. Some blocks are seismically active and others stable. The Pacific Basin to the east and the Tasman Basin to the west both have oceanic crusts about 5 km thick.

The sub-crust is traversed by a major wedge-shaped structure within which the deep-focus seismicity is confined. This has been named the "Sub-Crustal Rift", and its activity is apparently an extension of that associated with the Kermadec Trench. It follows a roughly south-west course from the Bay of Plenty to Farewell Spit, where it turns abruptly south-south-east and finishes close to the Alpine Fault.

Faults with both north-east and north-west trends are at present active. The most important of the north-west faults appears to run through Cook Strait. It is considered that the main crustal faults could have developed as the result of successive positioning above the Sub-Crustal Rift. Stable blocks have not been fractured in this way.

There is some evidence for a difference in crustal structure on opposite sides of the Rift. The western portion is about 5 km thicker, and contains a layer in which the P-velocities exceed 7 km/sec. No velocities above $6\frac{1}{2}$ km/sec have been observed in the eastern part. The western part thus has some features in common with continental crusts, while to the east the crust is of the type described elsewhere by the author as "insular".

There is no evidence of the arcuate structure suggested by some geologists: all the crustal and sub-crustal features appear to follow linear trends. The seismic picture thus differs at a number of points from that inferred from geological and other evidence, but seismology may offer a glimpse of a chapter of geology that is still being written. (Author's abstract slightly modified.)

58/42—ELLEN, P. E.: Concrete Aggregates in the Waikato - Thames - Bay of Plenty - Rotorua Districts. *N.Z. Concrete Construction 2 (2–5)*: 18–26, 48–50, 62–8, 77–9.

Forty-five aggregate deposits and plants were visited. Quarry sites in the four districts are shown by sectional maps. Short descriptions of most quarries include mention of geological conditions, plant, product rate and type; recommendations are made. The interpretation of the geological map of New Zealand is explained briefly.

In general it would seem that there is no real shortage of aggregate sources in the areas mentioned except perhaps in the Rotorua district, but even there a good deposit is within reasonable haulage distance. There is not available, however, technical advice, first, on locating the deposits and developing the sites economically and, secondly, on the plant layouts and equipment necessary to process the materials satisfactorily to conform to the requirements of the New Zealand Standard Specification 1051.

In Waikato district a western or Hamilton area and an eastern or Matamata - Te Aroha area are distinguished. In the Hamilton area the main useful aggregate is greywacke. The six western quarries listed are in deeply weathered greywacke. In the greywacke belt further west weathering is less, and development should be concentrated in this area. In Matamata - Te Aroha area four quarries work solid andesite and dacite, and two work andesite and rhyolite boulders.

In Thames - Coromandel district ten deposits and quarries are described, some in volcanic rocks, some in greywacke. If these deposits are to be developed economically, sound technical knowledge and geological investigation are needed.

Twenty Bay of Plenty aggregate sources are described. One or two plants in the area will produce good concrete aggregates, while others are generally small quarries and produce material basically for road works. The supply of material suitable for concrete aggregate and road sealing chips is definitely short but this is due to the inadequate plant facilities rather than to lack of suitable deposits.

In Rotorua-Taupo district the rocks are mostly rather soft, rhyolites, rhyolitic tuffs and ignimbrites, generally unsuitable as aggregates for dense impervious concretes. However, pumice, available from many pits, can be used extensively in special lightweight concretes. Good concrete aggregates include andesite at Manawahe and K-trig basalts on west shore of Lake Taupo. Karangahape basalt might require use with low-alkali cements. Present aggregate source for Rotorua is greywacke from Cambridge, and rhyolite from Ngongotaha, which is unsatisfactory. A greywacke gravel plant at Murupara produces good concrete aggregate. Tauhara dacite should prove useful for concrete and for exposed aggregate. (G.C.S.)

58/43—ELLIOTT, EILEEN L.: Sandspits of the Otago Coast. *N.Z. Geogr. 14 (1)*: 65–74, 3 figs.

Many of the rivers that flow to the sea between the mouth of the Clutha River and Oamaru, either have small catchment areas or deposit the larger part of their heavier load in intermontane basins. In consequence particles of sand grade predominate in detritus carried to the sea. Some of this detritus, the bulk of which is contributed by the Clutha River, is swept north-eastwards by an offshore current and is deposited subsequently to form sandspits in the numerous bays and inlets that abound on this coastline. The detailed topography of the spits varies from place to place, but with few exceptions they project from the northern headland and lie roughly parallel to the coast. (L.E.O.)

ELPHICK, J. O.: *See* 58/64.

58/44—EVISON, F. F.; INGHAM, C. E.; ORR, R. H.: The Thickness of the Earth's Crust in Antarctica. *Nature, Lond., 183 (4657)*: 306–8, 3 figs.

An earthquake on 9 September 1957, with epicentre in the south-east Indian Ocean provided records at Mirny, Scott Base, and Hallett Station from which it is calculated that the thickness of the crust in eastern Antarctica is about 35 km. The existence of a true antarctic continent is thus confirmed. A preliminary analysis of a second earthquake on 4 August 1957, in the south-west Indian Ocean indicates a similar crustal thickness. (B.W.C.)

58/45—FALCONER, B. H.: Departmental Building, Bowen Street, Wellington. Structural Aspects of Departmental Building. *N.Z. Engng. 13 (11)*: 390–9.

Includes (p. 396) brief geological interpretation of data from drillholes, and discusses soil mechanics of the site. (G.C.S.)

58/46—FELL, H. B.: Deep-Sea Echinoderms of New Zealand. *Zool. Publ. Victoria Univ. Wellington, 24,* 40 pp., figs.

Includes description of *Pseudechinus flemingi* n. sp. from off east Otago, Chatham Rise, and the Chatham Islands area (30 to 330 fathoms); the species is also recorded from Castlecliffian (Pleistocene) sediments near Wanganui. (C.A.F.)

FINLAY, H. J.: *See* 58/59.

58/47—FLEMING, C. A.: Darwinism in New Zealand: Some Examples, Influences, and Developments. (Hudson Lecture.) *Proc. roy. Soc. N.Z. 86*: 65–8, 9 figs.

Illustrations from New Zealand natural history of principles established by Darwin, referring to such subjects as the origin of the New Zealand flora, trans-oceanic dispersal of plants and animals, the evolution of flightless birds, melanism, polymorphism, and discontinuous distribution. The effects of Pleistocene glaciation on the distribution of alpine plants, and speciation under the influence of geographic isolation, are also discused, with some reference to evidence from fossils. (B.W.C.)

58/48—Fleming, C. A.: Upper Jurassic Fossils and Hydrocarbon Traces from the Cheviot Hills, North Canterbury. *N.Z. J. Geol. Geophys. 1 (2)*: 375–94, 16 figs.

Upper Jurassic fossils (*Buchia* aff. *malayomaorica*, *B.* aff. *subpallasi*, *Inoceramus* spp., *Anapaea* sp., and *Hibolithes brownei*) are recorded from the Cheviot Hills. The fossiliferous rocks have an oily smell when freshly crushed, and contain very small quantities of hydrocarbon, mostly methane. (Author's abstract.)

58/49—Fleming, C. A.: A New Species of *Sigapatella* (Gastropoda) from Cape Maria van Diemen, Northland, New Zealand. *Rec. Dom. Mus. (N.Z.) 3 (2)*: 141–3, 4 figs.

Sigapatella superstes n. sp. from Cape Maria van Diemen is characterised by its fine irregular spiral sculpture, shared among Australasian species only by *S. vertex* Marwick, an Eocene fossil from North Otago, and *S. otamatea* Laws, a Lower Miocene fossil from Kaipara Harbour. The survival in northernmost New Zealand of Mollusca formerly more widespread is discussed. (Author's abstract.)

58/50—Fleming, C. A.: On the Supposed Occurrence of *Tanea zelandica* Quoy and Gaimard (Naticidae) in New Caledonia. *J. Conchyliol. 97*: 141–2.

Study of specimens from New Caledonia indicates that the record of *Natica zelandica* from that island is in error and should probably be *N. ala-papilionis*. The latter may be a distant relative of *Tanea* Marwick (whose type species is *N. zelandica*), an endemic New Zealand genus that has been present in this country since the middle Tertiary. (B.W.C.)

Fleming, C. A.: *See also* 58/59 and 58/64.

58/51—Freneix, Suzanne: Contribution à l'Etude des Lamellibranches du Crétace de Nouvelle-Calédonie. *Sciences de la Terre, (Nancy), 4 (3–4)*: 153–207, 5 figs., 3 pls.

Systematic description of 35 species (including 14 new species and 5 new varieties) from the "Formation à Charbon" of New Caledonia, based on collections by M. Piroutet, J. Avias, and P. Routhier. Several species have close affinities in the Upper Cretaceous of New Zealand, including *Pacitrigonia hanetiana caledonica* n. subsp. *Pterotrigonia pseudocaudata* var. *dumbeae* n. var., *Linotrigonia (Oistotrigonia)*, *Eriphyla oblonga* n. sp. (compared with *E. meridiana* Woods), *Lahillia (Lahilleona) marwicki* n. sp. (compared with *L.* cf. *luisa* Wilckens), *Aphrodina* (= *Callistina*) (*Tikia*) *aviasi* n. sp. *A.* (*T.*) *garnieri* n. sp., *Dosinia* (*Dosinobia*) cf. *perplexa* Marwick, *Panopea malvernensis* Woods var. *quadrata* n. var.

The Senonian age of some of the species is confirmed by association with *Kossmaticeras* and *Baculites*. The affinity of the fauna is with those of New Zealand, Chile, South Patagonia, and Seymour Island – a well-defined South Pacific geographic realm in which the Upper Cretaceous lamellibranchs show a certain endemism. (C.A.F.)

Fyfe, H. E.: *See* 58/104.

Fyfe, W. S.: *See* 58/19.

58/52—Gage, M.: Late Pleistocene Glaciations of the Waimakariri Valley, Canterbury, New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 123–55, 17 figs.

Five distinct periods of major ice advance recorded in the Waimakariri Valley by a variety of glacial and glacifluvial deposits are distinguished by differences of elevation, surface gradients, distribution, weathering, and extent of defacement of original surface detail. Glaciations are grouped and named as follows: Avoca Glaciation (probably multiple, but not subdivided); Waimakariri Glaciation (comprising in chronological order Woodstock, Otarama, Blackwater, and Poulter advances, of which at least the last two were multiple). Interglacial deposits are rare. The Waimakariri glacier system was a complex pattern of ice streams including large tributaries mainly from the north-west, and distributaries between which transfluence occurred through numerous saddles. The ice in the middle reaches of the main valley was about 4,000 ft thick during the Avoca Glaciation, and perhaps from 500 ft to 1,000 ft thick at the height of later advances. Glacial geomorphic features are essentially the work of the later advances. The Avoca Glaciation, which was the most extensive, corresponds with the Waimaungan Glacial Stage and dates from early in the second half of the Pleistocene. An inter-glacial stage separates it from the last four advances, which together represent locally the Otiran Glacial Stage. The Otarama advance was the last occasion when ice reached as far as the eastern margin of the mountains, and outwash gravels from this advance built most of the Waimakariri segment of the Canterbury Plain. Several lakes existed temporarily during recessive phases, the largest lake having been at least 10 miles long in the main valley upstream from Poulter River. (Author's abstract.)

58/53—GAGE, M.: Geology. In "Handbook to the Arthur's Pass National Park", pp. 10–16, 2 figs. Arthur's Pass Nat. Park Board, Christchurch. 83 pp., ills.

The role of erosion in the development of the mountain and valley scenery is explained. The rocks consist mainly of greywacke and argillite, with rare fossils (*Monotis,* found in place only at Mt. Temple and in Bruce Creek) of Late Triassic age. The mountains are formed of blocks raised about the end of the Tertiary. The effects of earthquakes are noted, and of former more extensive ice action (moraines, cirques, scratched pebbles and surfaces). (B.W.C.)

58/54—GAGE, M.; SUGGATE, R. P.: Glacial Chronology of the New Zealand Pleistocene. *Bull. geol, Soc. Amer. 69 (5)*: 589–98, 3 figs.

Pleistocene glaciation of New Zealand has been recognised since about 1860, but multiple glaciation has gained general acceptance only recently. The glacial history is directly linked with the marine succession at Ross, Westland, where strongly folded early Pleistocene till, varve silts, and gravels conformably succeed marine Pliocene beds and are overlain unconformably by practically undeformed late Pleistocene moraines. Pleistocene culmination of the Kaikoura orogeny resulted in a clear distinction between early and late Pleistocene glacial deposits and probably explains a mid-Pleistocene hiatus in the successions.

In the proposed chronology, early Pleistocene glacial deposits are referred to the Ross glacial stage. Tectonically undeformed deposits that have accumulated since the present topography has existed are referred to two glacial stages (Waimaungan and Otiran) of the late Pleistocene separated by a full interglacial stage. Local names are given to four distinct advances of substage value recognisable within the Otiran stage. Field recognition depends upon differences in ice extent, erosion and weathering of deposits, and differences of altitude due to progressive lowering of river profiles.

There is as yet little basis for overseas correlation. The Otiran stage may extend farther back into post-Sangamon time than Wisconsin in the strict sense; correlation of Waimaungan with Illinoian is reasonable, though speculative. (Authors' abstract.)

58/55—GODWIN, H.; SUGGATE, R. P.; WILLIS, E. H.: Radiocarbon Dating of the Eustatic Rise in Ocean Level. *Nature, Lond. 181 (4622)*: 1518–9.

The Eustatic rise of the oceans to their present level, in the period between 14,000 and 6,000 years ago, as indicated by samples deposited close to their contemporary ocean-levels, is shown by a plot of radiocarbon age against depth. Samples from Christchurch, and Foxton, New Zealand, and others from the Gulf of Mexico, Melbourne, the Baltic, British Coasts, and the Persian Gulf were used. The graph gives consistent results which appear to establish a rapid rise of ocean level at a rate of approximately 3·0 ft per century and indicates that the present day level was attained about 5,500 years ago. (C.A.F.)

58/56—GOLDICH, S. S.; NIER, A. O.; WASHBURN, A. L.: A^{40}/K^{40} Age of Gneiss from McMurdo Sound, Antarctica. *Trans. Amer. geophys. Un. 39 (5)*: 956–8, 1 fig.

Biotite from paragneiss of Gneiss Point, McMurdo Sound, is dated at 520 million years by the argon-potassium method. Metamorphism of Precambrian sediments at the close of Precambrian or in Cambrian time is indicated. (From authors' abstract.)

58/57—GREGG, D. R.: Natural Heat Flow from the Thermal Areas of Taupo Sheet District (N 94). *N.Z. J. Geol. Geophys. 1 (1)*: 65–75, 2 figs.

Heat flow from the thermal areas of Taupo Sheet District has been estimated to be 274,000 kcal/sec (3,910 × 10^6B.Th.U./hr) above 0°c. The figure is based on measurements made during the period March 1951 to April 1952. The heat flow is equivalent to a loss of 24 × 10^{-6}cal/cm^2/sec over the whole area covered by the sheet. The heat flow could be produced by the flow upwards of 1,440 kg/sec of water with a temperature of 189°c. (Author's abstract.)

58/58—GREGG, D. R.: Reports of a Submarine Eruption off New Zealand in 1877. *N.Z. J. Geol. Geophys. 1 (3)*: 459–60.

Submarine eruptions were reported on 1 December 1877 near East Cape. They were probably not of volcanic origin but may have been a tsunami. (Author's abstract.)

58/59—GRINDLEY, G. W.: The Geology of the Eglinton Valley, Southland. *N.Z. geol. Surv. Bull n.s. 58*. 68 pp., 2 geol. maps, 28 figs.

This bulletin describes the geology of a 260 square mile rectanguar mountainous area on the eastern boundary of Fiordland in south-western New Zealand. This area is shown on a map on a scale of one mile to the inch. A geological map of western Otago and northern Southland (about 7,000 square miles) on a scale of four miles to the inch is also included in the bulletin, together with several geological sections. Acknowledgment is made to several other geologists for information used in compiling the small-scale map.

The rocks of the Eglinton Subdivision have been divided into five main stratigraphic units:

1. Fiordland Complex (Lower Paleozoic?): A group of thermally metamorphosed paragneisses and migmatites of diorite-amphibolite facies. The parent rocks were probably basic lavas, contemporary intrusions, tuffs, and volcanic-derived sediments of similar facies to the Eglinton Volcanics.

2. Te Anau System (Carboniferous and basal Permian): A highly-diversified assemblage of distinct stratigraphic and facies divisions. Caples Group consists of re-deposited geosynclinal greywackes and deepwater argillites. Eglinton Volcanics and Mackay Intrusives consist of andesitic and basaltic lavas and pyroclastics intruded by sills of soda granite, quartz diorite, dolerite, and granophyre. The names "Red Mountain Ultramafics" and "Livingstone Volcanics" are given to the ultramafic and volcanic portions of a conspicuous band of serpentine and associated spilitic lavas extending practically continuously for more than 100 miles on the east flank of the central syncline of Maitai rocks.

3. Maitai Series (Permian): Strongly compacted sandstones, argillites, slates, and limestones forming a distinctive sequence from limestone and sandstone at the base through grey-green and red laminated argillites to green sandstones, grits, and fine conglomerates at the top. The sequence can be matched, formation by formation, with the well-known Maitai Group in the Nelson district. It contains the following formations (in ascending order): Howden, Tapara, Winton, and Countess.

4. Lower Tertiary: Moderately-compacted freshwater sandstones, grits, and conglomerates with thin coal lenses, grading up into marine lower Oligocene sandstones. The sandstones are overlain by softer marine middle Oligocene limestones.

5. Late Pleistocene and Recent: The unconsolidated or slightly compacted moraines and outwash fluvio-glacial gravels of the Te Anau depression and lower Eglinton Valley are believed to belong to the last glacial stage of the Pleistocene. Postglacial deposits include river flats, fans, terraces, and swampy areas.

The relief between valley bottom and mountain top in the main valleys is 5,000 ft. All valleys have been glaciated, many of the valley-sides sloping as much as 30° to 45°. The mountain ranges trend south away from the southern end of the north-east-trending Southern Alps.

The Tertiary beds dip gently south-west below the Quaternary deposits and rise north-east to rest unconformably on the mountain ranges of Paleozoic basement rocks. Well-indurated coal-measure sandstones with beds of cemented quartz grit form steep, rugged foothills flanking the ranges. Their resistance to erosion is comparable with that of the basement rocks and they rise to heights of more than 5,000 ft. The most strongly disturbed Tertiary rocks (with dips of more than 60°) are infaulted along the west slopes of the Countess Range, but elsewhere dips in Tertiary sediments seldom exceed 30°.

Tertiary folds are generally open and follow the trends of the present topography, the ranges being anticlinal and the valleys synclinal. The most notable exception is a syncline along the west face of the Countess Range. The youngest folded sediments within the subdivision are Oligocene mudstones, but folded Miocene beds are preserved in the Te Anau depression farther south. The mountains can be dated as definitely post-Oligocene (probably post-Miocene) and pre-upper Pleistocene. The Hollyford Fault shows Recent vertical and lateral displacement.

The Paleozoic basement rocks form three north-trending mountain ranges separated by deep glaciated valleys. They are strongly folded and strike-faulted. Unlike the Tertiary structures, the basement structures are unrelated to the present topography. Several anticlines, synclines, and faults are named and described.

The Eglinton Subdivision contains no minerals or rocks of economic importance. A belt of serpentine rock occupies 20 square miles in the eastern part, but is so remote from the nearest road that it is unlikely to be of value even in the distant future. Small lenses of limestone at the base of the Maitai Series are also difficult of access. The plutonic and volcanic rocks of the Eglinton Valley have some potential value as ornamental building stones. Some prospecting for radioactive minerals has been done, but without success. Large areas of coal measures occur but no coal seams are of payable thickness.

An appendix lists the localities from which fossil samples have been collected and includes faunal lists with brief notes by H. J. Finlay, J. Marwick, and C. A. Fleming. (B.W.C.)

58/60—GUNN, B. M.: Exploration and Adventure in the Antarctic: The Trans-Antarctic Expedition, 1956–58. (1) The Northern Field Party. *N.Z. alpine J. 17 (45)*: 303–15; maps, photos.

Includes brief references to geology – the occurrence of *Glossopteris* (Permian) in the upper part of the Mawson Glacier, and the types of rocks found, including coal. (B.W.C.)

58/61—HAMILTON, D.: An Eocene Sea-Pen from Dunedin, New Zealand. *Palaeontology 1 (3)*: 226–30, 1 pl., 2 figs.

A new Upper Eocene pennatulid from the Burnside Mudstone, Dunedin, is described and named *Bensonalaria spatulata* n. gen., n. sp. It is assigned to the Family Veretillidae. (Author's abstract.)

58/62—HARRINGTON, H. J.: Beaufort Island, Remnant of a Quaternary Volcano in the Ross Sea, Antarctica. *N.Z. J. Geol. Geophys. 1 (4)*: 595–603, 5 figs.

Beaufort Island, near the entrance of McMurdo Sound, is a remnant of a basaltic cone of about Last Interglacial age. More than three-quarters of it was quarried away by extensions of the Ross Ice Shelf or by glaciers during the Last Glaciation, leaving the remainder essentially unmodified. Agglomerates, lavas, and tuffs of the cone rest unconformably on a pediment of horizontal tuffs and fine agglomerates, which show features that are either frozen-ground involutions or contortions caused by collapse of ice-tuff sandwiches. On the northern shore there is a cliffed bench at a height of about 25 ft. Its age and origin are uncertain but it could be a cliffed talus cone formed about 700 A.D., or a true marine bench formed about 5000 B.C. and since raised by post-glacial isostatic rebound of Antarctica. (Author's abstract.)

58/63—HARRINGTON, H. J.: Nomenclature of Rock Units in the Ross Sea Region, Antarctica. *Nature. Lond. 182 (4631)*: 290.

A nomenclature for major regional rock units was devised at a meeting of 10 British Commonwealth geologists in Wellington. The names proposed were Ross System, Admiralty Intrusives, Beacon System, Ferrar Dolerites, and McMurdo Volcanics. (B.W.C.)

58/64—HARRINGTON, H. J.: Geology of Kaitangata Coalfield. *N.Z. geol. Surv. Bull. n.s. 59.* viii + 131 pp., geol map, 24 figs.; 13 maps and 14 sections in separate folder.

This Bulletin describes in detail the stratigraphy, structure, and coal resources of Kaitangata Coalfield in eastern Otago about 50 miles south-west of Dunedin. Production ranges between 70,000 and 160,000 tons a year but has been slowly declining. Total reserves are estimated at more than 100 million tons. Proved and probable reserves are more than adequate to meet normal production for the next 50 years. At present the coalfield is a marginal one, but if the level of industrial activity in New Zealand is raised it could be developed on a moderately large scale and be of much greater importance in the country's economy, especially if the large "inferred reserves" estimated by the author are proved by drilling to exist. One advantage of the coalfield is the large amount of coal that could be worked by cheap mechanised opencast methods.

The basement rocks consist of geosynclinal sediments and associated volcanics many thousands of feet thick, and chlorite schists also of considerable thickness. The schistose rocks form the Tuapeka Group and are thought to be of Late Paleozoic age. Permian fossils have been found in the Clinton Formation, and a mid-Triassic marine fauna in the Kaihiku Formation.

The Paleozoic and Lower Mesozoic rocks are overlain unconformably by soft or loosely-compacted terrestrial and marine rocks of Cretaceous and Tertiary age. Detailed mapping has shown that the greywacke conglomerates at Kaitangata (the type beds of Ongley's Kaitangata Series) grade laterally into the quartz conglomerates of Ongley's Taratu Series. The name Kaitangata is therefore abandoned as a formation name, and the greywacke and schist conglomerates and breccias forming the lowest unit of the covering strata are called Henley Breccia. This is overlain unconformably by the Taratu Formation consisting of coal measures with two types of conglomerates, one consisting of quartz pebbles and the other of greywacke pebbles and cobbles. The detailed stratigraphy of this formation is described at length in chapter 3, where it is divided into a number of members and coal-horizons. A coal-horizon is defined as a more or less continuous set of fine beds (silts, mudstones, sands) which may contain one or more coal seams. The coal seams may split, thin, thicken, or pinch out, or may be absent over large areas.

Overlying the Taratu Formation is the Wangaloa Formation of terrestrial quartz-pebble conglomerates passing laterally into marine fossiliferous quartz-pebble conglomerate with a fauna of Danian or Paleocene age. The Elliotvale Formation of Bortonian and Kaiatan age (Middle and Upper Eocene) is of restricted distribution, and there are several small occurrences of Late Tertiary igneous rocks – sodic and basic lava flows and small intrusions.

The history of coal mining and the properties, quantities, and exploitation of the coals are discussed. The section on "Coal Analyses" is contributed by J. O. Elphick. Paleontological notes by C. A. Fleming and N. de B. Hornibrook are included in the stratigraphic sections. In appendices are lists of drillholes, logs of selected drillholes, logs of shafts and drives, and lists of mines. (B.W.C.)

58/65—HARRINGTON, H. J.; MCKELLAR, I. C.: A Radiocarbon Date for Penguin Colonization of Cape Hallett, Antarctica. *N.Z. J. Geol. Geophys. 1 (3)*: 571–6, 1 fig.

During maxima of ice advances in the Last Glaciation, 10,000 to 30,000 years ago, the Ross Sea was filled by ice, so penguin colonisation of shoreline breeding sites must have occurred since that time. The age of a frozen Adélie penguin body from the base of an accumulation of penguin bodies and guano at the Cape Hallett rookery has been determined by the radiocarbon method as 1,210 ± 70 years. The rookery was probably colonised between about 400 and 700 A.D., at approximately the same time as a Northern Hemisphere warm period that stimulated a Viking expansion. There is no sign that it was temporarily abandoned at the time of a Northern Hemisphere cold period between 1650 and 1750 A.D. (Author's abstract.)

58/66—HARRINGTON, H. J.; WOOD, B. L.: Quaternary Andesitic Volcanism at the Solander Islands. *N.Z. J. Geol. Geophys. 1 (3)*: 419–31, 9 figs.

The Solander Islands are erosional remnants of a major volcano consisting of dacitic hornblende-biotite-andesite in the form of lava, tuff, agglomerate, and dikes. Indirect evidence suggests that the rocks are about Upper Pleistocene in age. The volcanism is curiously isolated, the nearest comparable rocks of Tertiary or Quaternary age being at Mt Egmont, 640 miles to the north-north-east. This isolation is a problem of Quaternary tectonics.

An appendix (pp. 430–1, fig. 9) by J. W. Brodie, "The Sea-floor around the Solander Islands," shows that the islands rise from the outer edge of the continental shelf, and briefly describes the Solander Trough. This last feature lies to the south of the islands, with branches to both east and west of them. The easterly branch is aligned with the Waiau syncline. (Authors' abstract modified.)

58/67—HARRIS, W. F.; Pollen Analysis and Archaeology. *N.Z. Sci. Rev. 16 (3–4)*: 27–28.

A Maori wooden scoop dug up from a depth of four feet in peat at Paraparaumu was used to test whether sufficient pollen could be recovered for correlation with a stratigraphic horizon. It was possible to remove from the grain of the wood, with the point of a scalpel, material for a pollen preparation which yielded thousands of pollen grains and spores. The presence of pollen of *Plantago* and other weeds of cultivation suggests that the pollen spectrum is related to the period following European settlement. (W.F.H.)

58/68—HATHERTON, T.: Antarctic Research. *Nature, Lond. 182 (4631)*: 285–9, 1 fig.

Report of an informal symposium on Antarctic research held in New Zealand in February 1958. Refers to glaciology, the topography of the sub-glacial continent, oceanography, and seismology. (B.W.C.)

HATHERTON, T.: *See also* 58/12.

58/69—HILLS, E. S.: William Noel Benson, 1885–1957. (Obituary.) *Biographical Memoirs of Fellows of the Royal Society*, 4: 27–33, portrait.

Includes biography. *See also* 58/14.

HISCOCK, I. D.: *See* 58/96.

58/70—HORNIBROOK, N. DE B.: New Zealand Upper Cretaceous and Tertiary Foraminiferal Zones and Some Overseas Correlations. *Micropaleontology 4 (1)*: 25–38, 1 pl., 2 tables.

On the basis of Foraminifera, New Zealand Upper Cretaceous and Tertiary stages are correlated with the international time scale as follows: Haumurian with Maestrichtian; Teurian with Danian; Waipawan with Paleocene; Mangaorapan and Heretaungan with Lower Eocene; Porangan and Bortonian with Middle Eocene; Kaiatan and Runangan with Upper Eocene; Whaingaroan and Duntroonian with Lower Oligocene; Waitakian with Middle Oligocene; Otaian with Upper Oligocene (Chattian); Hutchinsonian and Awamoan with Upper Oligocene or Lower Miocene; Altonian with Lower Miocene (Aquitanian); Clifdenian with Upper Aquitanian or Burdigalian; Lilburnian and Waiauan with Middle Miocene; Tongaporutuan and Kapitean with Upper Miocene; Opoitian and Waitotaran with Pliocene. There is as yet no microfaunal evidence for the Pliocene-Pleistocene boundary in New Zealand. Some pelagic Foraminifera described by Finlay from New Zealand are refigured, and notes, including descriptions and a proposal of a new species of Paleocene *Globigerina* (*G. pseudoiota*) are appended. (Author's abstract.)

58/71: HORNIBROOK, N. DE B.: New Zealand Foraminifera: Key Species in Stratigraphy – No. 6. *N.Z. J. Geol. Geophys. 1 (4)*: 653–76, 36 figs.

The following Foraminifera, of stratigraphic importance in New Zealand and especially in the Waipara district, North Canterbury, are figured and described: *Pseudoclavulina anglica* Cushman (Teurian); *Sigmoilopsis neocelata* n. sp. (Duntroonian? Waitakian to Altonian); *S. compressa* n. sp. (Awamoan and Altonian); *Buliminella waiparaensis* n. sp. (Haumurian and Teurian); *Bolivina fyfei* n. sp. (Kapitean to Nukumaruan); *Loxostomum pakaurangiensis* n. sp. (Awamoan to Waiauan); *Notorotalia wilsoni* n. sp. (Altonian to Waiauan); *Notorotalia aranea* n. sp. (Otaian? Hutchinsonian and Awamoan); *Globigerina pseudoiota* Hornibrook (Waipawan and Mangaorapan); *G gravelli* Bronniman (Waipawan); *G. soldadoensis* Bronniman (Waipawan); *Globorotalia zealandica* n. sp. (Awamoan and Altonian); *Cibicides thiaracuta* n. sp. (Altonian to Tongaporutuan). (Author's abstract.)

HORNIBROOK, N. DE B.: *See also* 58/64.

58/72—HUTTON, C. O.: Notes on Tapiolite, with Special Reference to Tapiolite from Southern Westland, New Zealand. *Amer. Mineral. 43 (1–2)*: 112–9.

Rare particles of tapiolite have been found in beach sand north-east of the mouth of Cook River, Westland. Optical and X-ray properties are recorded. [The generalised formula for tapiolite is (Fe, Mn) (Nb, Ta)$_2$O$_6$.] (H.J.H.)

HUTTON, C. O.: *See also* 58/34.

58/73—ICHIKAWA, K.: Zur Taxionomia und Phylogenie der Triadischen "Pteriidae" (Lamellibranch). *Palaeontographica A, 111 (5–6)*: 132–212.

Triassic lamellibranch genera formerly classed as Pteriidae are attributed to other families: *Claraia* to the Pseudomonotinae, *Eumorphotis* to the Aviculopectininae, *Oxytoma* and *Meleagrinella* to the Oxytominae nov., all in the Aviculopectinidae, whereas *Monotis* must be classed in the Monotidae, *Halobia* and *Daonella* in the Halobiidae. *Entomonotis* is placed as a subgenus of *Monotis*, *Enteropleura* and *Veldidenella* as subgenera of *Daonella*. New diagnoses and descriptions of type species are presented (including figures from primary type material of *Monotis richmondiana* Zittel from Richmond, Nelson, New Zealand) together with included species, stratigraphic and geographic distribution, and remarks on systematic status and phylogeny. Post-Triassic groups, Aucellinae (sic) and Aulacomyelinae nov., are also discussed.

The Triassic genera, hitherto grouped under Pteriidae, belong to at least three phylogenetically separate major groups.

One family (Cassianellidae), two subfamilies (Oxytominae and Aulacomyellinae) and one subgenus (*Hypoxytoma*) are proposed as new, and several new names (including *Krumbeckiella* n. nov. for *Timoria* Krumbeck) are proposed for preoccupied names. (C.A.F.)

INGHAM, C. E.: *See* 58/44.

58/74—KEAR, D.: Notes on Four Minor Sulphide Prospects near Coromandel. *N.Z. J. Geol. Geophys. 1 (3)*: 514–8, map.

Four sulphide prospects near Coromandel proved, on investigation, to be either too low-grade or too small to be economic. However, they include examples of preferential pyritisation of carbonaceous beds, of very rich pyritisation and associated intense propylitisation that is apparently structurally rather than lithologically controlled; and of areal pyritisation of andesites (2% to 6% pyrite.) (Author's abstract.)

58/75—KEAR, D.: The Geological History of the Waikato Basin. *Proc. N.Z. Soc. Soil Sci. 3*: 30–1. [1959.]

Over 30,000 feet of marine sediment, including tuffaceous beds, accumulated in Triassic-Jurassic times. Following uplifting earth movements, marine conglomerates and terrestrial beds were added to the sedimentary pile, and the hardened rocks were folded to form a new land. Erosion, followed by transgression, led to the deposition of coal measures and marine beds in the lower Tertiary. Upper Miocene earth movements tilted these rocks gently, and volcanism commenced and has continued to the present day. Pliocene and Quaternary deposition included alluvial volcanic sediments (which were alternately deposited and eroded depending upon climate, vegetational cover, and volcanic violence), coastal sandhills and plains, as well as andesitic and basaltic cone deposits and volcanic ashes. (D.K.)

58/76—KEYES, I. W.: Blackstone. *J. Polynes. Soc., 67 (2)*: 158–61, map.

Blackstone is a descriptive term for a rock frequently used by the Maoris and their predecessors in New Zealand, for stone adzes. It is a contact-metamorphosed argillite or hornfels, the best quality of which is found in the Mineral Belt of Nelson. Several Maori quarries in this district are mentioned, including many on D'Urville Island. The rocks of the Mineral Belt are now included in the Te Anau Group, and the hard baked argillite occurs as lenses, pockets, and large boulders in serpentine and also on the west edge of the belt. The name "metamorphosed argillite" is preferable to the obsolete term "black aphanite" and is more precise than "blackstone". (B.W.C.)

58/77—KING, L. J. The Agricultural Lime Industry of the South Island. *N.Z. Geogr. 14 (2)*: 115–130, maps.

The South Island lime industry, which began in 1880 with a lime kiln at Milburn, had, in 1955, 70 lime-crushing plants producing 1,004,000 tons annually. Early in this century production changed from burnt to crushed lime, and in the 1940's the use of the conventional blasting methods of quarrying began to wane in favour of the use of rooters for breaking up the limestone in the quarry. The distribution of limeworks has been determined not only by the occurrence of suitable outcrops of limestone and their proximity to the farming areas to be served, but also by the government subsidy on the transportation of lime. (L.E.O.)

58/78—KINGMA, J. T.: The Tongaporutuan Sedimentation in Central Hawke's Bay. *N.Z. J. Geol. Geophys., 1 (1)*: 1–30, 25 figs.

The distribution of the thickness of sediments in Central Hawke's Bay indicates that a trough-like basin existed in the upper Miocene. Into this basin a thick sequence of graded, banded sediments was deposited, while at the same time a thin sequence of unstratified beds was laid down in the area surrounding the basin. An investigation of the grain sizes in the basin revealed that the sediments were brought in from the east, presumably across a bar which is thought to have separated the basin from the open ocean.

Kuenen and Migliorini's theory that graded sediments are deposited by turbidity currents cannot be applied satisfactorily. The banded sequences of the upper Miocene and their massive equivalents show that these beds must have developed by a different mechanism. It is suggested that both the above-mentioned basin and the bar subsided irregularly and intermittently, the basin subsiding more than the bar. As a result, the relation between bar-depth and basin-depth varied continually. Consequently there were changes in the speed and strength of currents across the bar. Grain size and the amount of sediment carried into the basin by these currents changed rapidly, causing banded sediments with vertical grading. (Author's abstract abridged.)

58/79—KINGMA, J. T.: Geology of the Wakarara Range, Central Hawke's Bay. *N.Z. J. Geol. Geophys. 1 (1)*: 76–91, 11 figs.

The Wakarara Range is a Jurassic(?) greywacke piercement body flanked on the western and southern sides by faults, and on the eastern side by steep-dipping upper Pliocene rocks. The range is separated from the main greywacke block of the Ruahine Range by a long narrow graben – the Ohara depression. Marine sedimentation in the Ohara depression started at least as early as middle Pliocene (lower Waitotaran) and continued until early Pleistocene (lower Nukumaruan) time, when the sea regressed and thick sequences of conglomerates were deposited on a truncated surface of Waitotaran rocks. The Wakarara piercement body emerged in latest Waitototaran time; the southern part rose above sea level first. Movement of the Wakarara block as a whole took place in a southerly direction. (Author's abstract.)

58/80—KINGMA, J. T.: Possible Origin of Piercement Structures, Local Unconformities, and Secondary Basins in the Eastern Geosyncline, New Zealand. *N.Z. J. Geol. Geophys. 1 (2)*: 269–74, 2 figs.

Piercement structures, local unconformities, and secondary sedimentary basins observed in the Eastern Geosyncline are often closely associated with transcurrent fault-zones. Spasmodic and uneven transcurrent movement along these fault-zones is thought to be responsible for the features. Their probable development is shown diagrammatically. (Author's abstract.)

58/81—KINGMA, J. T.: The Structural Position of the Opau Greywackes, Hawke's Bay. *N.Z. J. Geol. Geophys. 1 (3)*: 490–500, 3 figs.

A structure in the young Tertiaries of the Patoka district, northern Hawke's Bay, is anomalous when the area is compared topographically with districts further north and south. A faulted body consisting of greywackes of probable Jurassic Age has pushed the Tertiary and its lower Pleistocene cover up, and initiated the local anomalous topography. The action started in Nukumaruan time. The movement had a mild southern component causing disturbance in the area immediately north of the Opau greywackes. (Author's abstract.)

58/82—KOLB, A.: Historische Gletscherschwankungen auf der Südhalb-Kugel, insbesondere auf Neuseeland. In *Geographische Forschungen, Festschrift zum 60 Geburtstag von Hans Kinzl. Schlern Schriften 190*: 123–46, 4 figs. (maps), 8 photos., folding map. (Innsbruck.)

The translated title of this publication is "Historic Variations in Glaciers in the Southern Hemisphere, particularly in New Zealand." It forms one contribution in the "anniversary volume" published for the 60th birthday of Hans Kinzl. A translation has been made in the Translation Section of N.Z. Dep. Sci. Industr. Research, and distributed by the Christchurch Office of the N.Z. Geological Survey.

The author spent some three months in New Zealand in 1952 and investigated the "forefields" of the Mueller, Hooker, Tasman, Fox, and Franz Josef Glaciers, collecting data for a comparison with the situation in the European Alps. The recent moraines of these glaciers are described and the author also reviews the literature on these and other New Zealand glaciers. Some reference is made to the glaciers of South America, Africa, and New Guinea. The author concludes: ". . . a comparison of the southern hemisphere glaciers with one another, and also with the glaciers of the European Alps, shows a broadly based and extensive agreement in the phases of advance and in the general retreat, such that there can no longer be any doubt as to the synchronism of historic variations in glaciers over the whole earth".

The paper includes a bibliography of 88 references, many of which refer to New Zealand. (B.W.C.)

58/83—KRENEK, L. O.: The Formation of Dirt Cones on Mount Ruapehu, New Zealand. *J. Glaciol. 3 (24)*: 312–4, 7 figs.

Because of the abnormally warm summers of 1955 and 1956 the glaciers of Mount Ruapehu deteriorated to such an extent that the ash layer of the eruption of 1945 was exposed everywhere. This caused a development of ice cones similar to those occurring in Iceland. Various factors, especially heavy crevassing, which took place at the same time, are responsible for the different ways of development of dirt cones on Ruapehu. (Author's abstract.)

58/84—LEAMY, M. L.: Pleistocene Shorelines at Porirua Harbour, near Wellington, New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 95–102, 4 figs.

Correspondence of the heights of ancient shore-line features found near the northern and eastern shore lines of the Pauatahanui Inlet of Porirua Harbour with heights of Pleistocene shore lines overseas is remarkably close. Although Porirua Harbour lies in a tectonically unstable environment, a hypothesis advanced by Cotton (1952) suggests that the Harbour itself may have largely escaped the effects of recent differential earth movements. Pleistocene shore lines could well be preserved in such a locality, and terraces are correlated by height with the (postglacial) thermal maximum, Late Monastirian, Main Monastirian, Tyrrhenian, Milazzian, and Sicilian shorelines of other regions. (Author's abstract modified.)

58/85—LENSEN, G. J.: The Wellington Fault from Cook Strait to Manawatu Gorge. *N.Z. J. Geol. Geophys. 1 (1)*: 178–96, 9 figs.

Air photo interpretation of Recent and Late Pleistocene faults shows the Wellington Fault to be a transcurrent clockwise (dextral right-lateral) fault extending from Cook Strait to the point west of Lake Waikaremoana, where it branches into several faults extending into the Bay of Plenty. Details are given of Recent displacements (determined by interpretation of air photographs) along the Wellington Fault between Cook Strait and the Manawatu Gorge. (Author's abstract extended.)

58/86—LENSEN, G. J.: Note on Fault Correlations across Cook Strait. *N.Z. J. Geol. Geophys. 1 (2)*: 263–8, 2 figs.

Two methods are suggested for linking the active transcurrent faults in the North Island and the South Island across Cook Strait. One uses the average lateral displacements along the faults, the other the location of epicentres. Both methods give the same fault pattern. (Author's abstract.)

58/87—LENSEN, G. J.: Rationalized Fault Interpretation. *N.Z. J. Geol. Geophys. 1 (2)*: 307–17, 7 figs.

The ratio of the horizontal and vertical components of displacement along a fault can be used to determine the character of the faults, and the direction of the principal horizontal stress. The technique is applied to field examples.

A classification of faults, based on this ratio and the direction of the principal horizontal stress, is proposed and a new fault symbolism is suggested. The method is applied to fault-plane solutions proposed by Hodgson and tabulated by Scheidegger. (Author's abstract.)

58/88—LENSEN, G. J.: Note on the Compressional Angle between Intersecting Transcurrent Clockwise and Anticlockwise Faults. *N.Z. J. Geol. Geophys. 1 (3)*: 533–40, 1 fig.

It is shown that the compressional angle between intersecting major transcurrent clockwise and anti-clockwise faults is acute in tensional, and obtuse in compressional regions. (Author's abstract.)

LENSEN, G. J.: Measurement of Compression and Tension: Some Applications. *N.Z. J. Geol. Geophys. 1 (3)*: 565–70, 3 figs.

Stress can be equated to vertical and horizontal fault displacements. Plotted on a map of New Zealand, the pattern of isallo-stress lines corresponds with that of Bouguer gravity anomalies. The regions of tension correspond with those of large negative gravity anomaly, while the compressional regions correspond with those of small negative and of positive gravity anomalies. (Author's abstract.)

58/90—LENSEN, G. J.: A Method of Graben and Horst Formation. *J. Geol. 66 (5)*: 579–87, 14 figs.

Grabens and horsts between transcurrent faults in New Zealand, currently explained by normal faulting, are shown to be caused by lateral displacement. The mechanics of the formation of such features is explained. The theory of transcurrent fault grabens is based on the assumption that within the same stress system the friction along fault planes decreases from reverse faults (compressional) through transcurrent faults to normal faults (tensional). (Author's abstract extended.)

58/91—LILLIE, A. R.: On Collecting Rocks. *N.Z. alpine J. 17 (45)*: 440–4.

An invitation to mountaineers to collaborate in the investigation of the geology of the New Zealand Alps by collecting rock specimens. Hints on the most useful types of specimens and on the details to be forwarded with them are given. (B.W.C.)

58/92—LIPSON, J.: Potassium-Argon Dating of Sedimentary Rocks. *Bull. geol. Soc. Amer. 69 (2)*: 137–150, 7 figs.

Results in the potassium-argon dating programme at Berkeley are reported. Geologically well-classified authigenic sediments ranging from Miocene (12 m.y.) to Givetian (285 m.y.) have been analysed utilising equipment designed to date materials of low radiogenic argon content. Age determinations of seven glauconites from the Oligocene (30 m.y.), Eocene (45 m.y.), and Paleocene (55 m.y.) of New Zealand are consistent with the stratigraphy and correspond to the few previous U-Pb and K-A dates for that segment of the geological time scale. Ages of three Miocene glauconite samples from New Zealand are anomalously high compared to those of the Oligocene samples, which may be too low. The age for an Albian glauconite from Canada is too high compared to that of other samples dated. Dating of a Cenomanian feldspar and a Givetian sylvite from Canada is consistent with the Holmes B time scale. Possible explanations are offered for the discrepancies, and further experiments are suggested. (C.A.F.)

58/93—MCGHIE, T. H.: How It All Began . . . The Story of Coal. *N.Z Coal 3 (2)*: 2–5; *3 (3)*: 2–4; also *3 (4)*: 2–5 (1959).

A series of popular illustrated articles on the origin of the earth and of coal, the early use of coal, the development of coal mining, and the influence of coal on industry. (B.W C.)

MCKELLAR, I. C.: *See* 58/65 and 58/125.

58/94—MCKELVEY, P. J.: Forest History and New Zealand Prehistory. *N.Z. Sci. Rev. 16 (3–4)*: 28–32.

Radiocarbon dating has helped in interpreting forest development and in recognition of stages in forest succession. Indigenous forests have persisted during glacial encroachments of the Pleistocene, have colonised vast areas of tundra and grassland with the post-glacial amelioration of climate, have been modified by post-glacial climatic oscillations, have been affected (in the North Island) by intermittent volcanic bombardment, and latterly have been reduced by extensive burning and land-clearing in pre-European as well as post-European times. (W.F.H.)

58/95—MCMICHAEL, D. F.: The Nature and Origin of the New Zealand Freshwater Mussel Fauna. *Trans. roy. Soc. N.Z., 85 (3)*: 427–32.

The recent freshwater mussels of New Zealand are reviewed and compared with those of Australia. The fossil species are discussed and it is concluded that they are not good evidence for an evolutionary sequence that would account for the recent species. The hypothesis of a land bridge to account for the origin of the freshwater mussels is reviewed and rejected. As an alternative it is suggested that they were derived by transfer of Australian stocks across the Tasman Sea by birds. (From author's abstract.)

58/96—MCMICHAEL, D. F., and HISCOCK, I. D.: A Monograph of the Freshwater Mussels (Mollusca, Pelecypoda) of the Australian Region. *Aust. J. mar. Freshwater Res. 9 (3)*: 372–508, 19 pls.

Includes a discussion of the distribution and phylogeny of the living forms, including the three New Zealand species which are probably of fairly recent origin, as is the river system. Five introductions across the Tasman from Australia would be necessary to account for the known New Zealand species; a Mesozoic transfer of *Protovirgus* stock (*P. flemingi* McMichael, Upper Cretaceous); a transfer of *Velesunia* stock to give rise to *V. huttoni* McMichael (Oligocene); two transfers of *Hyridella* stock to give rise to the living *H. (H.) aucklandica* and *H. (Echyridella* n. subgen.) *menziesi*; and one transfer of *Cucumerunio* stock to give rise to *C. websteri*. Transfer by birds is favoured. (C.A.F.)

58/97—MARSHALL, T.; SUGGATE, R. P.; NICHOLSON, D. S.: A Borehole Survey of Ilmenite-bearing Beach Sands at Cape Foulwind, Westport. *N.Z. J. Geol. Geophys 1 (2)*: 318–24, 1 fig.

Posthole boring of dune sands on Nine Mile Beach, south of Cape Foulwind, Westport, shows that the surface sand to a depth of 20 ft contains an average of 5·5% of magnetically recoverable ilmenite.

Boring of dunes covering approximately half of Nine Mile Beach, has proved more than one million tons of ilmenite in sands above ground-water level. This represents only a small fraction of the total ilmenite present, above and below ground-water level, over the full extent of Nine Mile Beach. (Authors' abstract.)

MARTIN, W. R. B.: *See* 58/103.

MARWICK, J.: *See* 58/59.

58/98—MASON, B. H.: The Intrusive Rocks of the Kaikoura Mountains, Marlborough, New Zealand. *Trans. roy. Soc. N.Z. 85 (2)*: 247–62, 4 pls., 1 fig.

The intrusive rocks of the Kaikoura Mountains are mainly gabbros, consisting of varying amounts of plagioclase, olivine, augite, and brown hornblende. Associated with these gabbro intrusions are numerous sills of diverse composition, ranging from extremely mafic to extremely felsic types. The mineralogy and petrography of these rocks are described, and chemical analyses of a hornblende gabbro, a camptonite, a nepheline syenite aplite, and a basalt are given. Analyses are also given of coexisting hornblende and biotite from the gabbro. The rock series is alkalic in nature, with an alkali-lime index of 50·4. The distribution of the different areas of these rocks indicates that they have been separated by transcurrent faulting since intrusion, which is believed to have occurred during the Hokonui Orogeny (Upper Jurassic?). (Author's abstract.)

58/99—MOAR, N. T.: Contributions to the Quaternary History of the New Zealand Flora. 1. Auckland Island Peat Studies. *N.Z. J. Sci. 1 (3)*: 449–66, 9 figs.

Peat stratigraphy and peat vegetation were studied over a small area of Auckland Island in the vicinity of Port Ross. Samples were collected for pollen analysis, and the results from four profiles are presented. No detailed correlation with published pollen analyses from the southern hemisphere has been made, but the consistent maximum of *Metrosideros* pollen forms a basis for dividing the profiles into three stages, and it is suggested that the *Metrosideros* maximum is synchronous with the warm, forest period which obtained in New Zealand between the seventh and fourteenth centuries.

Brief notes are given on some pollen types, and the first appearance of Centrolepidaceae pollen in New Zealand peats is recorded. A note on long-distance transport of pollen discusses the presence of pollen of *Podocarpus*, *Dacrydium*, and *Nothofagus* in the profiles. These genera do not occur on the Auckland Islands. (From author's abstract.)

58/100—MOAR, N. T.: Contributions to the Quaternary History of the New Zealand Flora. 2. Plant Remains from a Buried Peat Layer at Bowenvale, Christchurch. *N.Z. J. Sci. 1 (3)*: 480–6, 3 figs.

Plant fragments from a peat layer three feet thick and buried by five feet of silt are listed and are briefly discussed. Wood from the base of the profile has been assigned an age of 940 ± 70 years by the ^{14}C method. (Author's abstract.)

58/101—N.Z. GEOLOGICAL SURVEY: Geological Map of New Zealand (1 : 2,000,000). Dept. Sci. Industr. Research, Wellington.

A coloured geological map on a single sheet, approximately 24 × 36 inches, on which the rocks of New Zealand are divided into 40 units as compared with the 23 units shown on the 1 : 1,013,760 (16 miles to 1 inch) map published (in two sheets) in 1947. The chief differences are the mapping of many new igneous and metamorphic rock units, and closer subdivision of the pre-Mesozoic sediments. (B.W.C.)

NEYLAND, P. A.: *See* 58/16 and 58/17.

58/102—NICHOLSON, D. S.: Utilisation of Coal in New Zealand 1920–1955. *N.Z. Dep. sci. industr. Res. Inform. Ser. 19.* 50 pp., 13 figs.

Includes a brief review of the coal resources of New Zealand, a description of the types of coal and their production, and suggestions for research. (B.W.C.)

NICHOLSON, D. S.: *See also* 58/97.

58/103—NICHOLSON, D. S.; CORNES, J. J. S.; MARTIN, W. R. B.: Ilmenite Deposits in New Zealand. *N.Z. J. Geol. Geophys. 1 (4)*: 611–6, 1 fig.

A reconnaissance survey shows that on the South Island West Coast beaches between Karamea and Jacksons Bay there is available upwards of 1,000 million tons of dredgeable sand from which ilmenite and small amounts of radioactive minerals and gold could be recovered. The most important locality is immediately south of the Buller River, near Westport. Brief mention is made of ilmenite in the North Island. (*See also* 58/104.) (From authors' abstract.)

58/104—NICHOLSON, D. S.; FYFE, H. E.: Borehole Survey of North Island Ironsands from New Plymouth to Kaipara Harbour. *N.Z. J. Geol. Geophys. 1 (4)*: 617–34, 11 figs.

A reconnaissance survey shows that on the beaches between the mouth of the Mokau River and the township of Muriwai there is available more than 600 million tons of magnetically recoverable ironsand assaying 58% iron. The deposits are also considered as a source of ilmenite.

The most important deposit, near Lake Taharoa, contains some 173 million tons of ironsand in concentrations varying from 41% iron in dune sands to 87% iron in beach concentrates. (Authors' abstract modified.)

NIER, A. O.: *See* 58/56.

58/105—ODELL, N. E.: The Structure of the Southern Alps. *N.Z. alpine J. 17 (45)*: 429–40, 10 photos.

After pointing out the almost complete absence of volcanism in many of the major mountain ranges of the earth (including the Southern Alps), the author refers to the importance of folding, faulting, and thrusting in the formation of this range. The rocks are more uniform than those of the European Alps and geological structures so far known are less complex. The relative scarcity of fossils and distinctive marker beds makes the elucidation of structure more difficult.

The Southern Alps appear to be a partially folded and compressed block of country, which has been uplifted and generally tilted south-eastwards. Relatively gentle folds may be seen in the walls of valleys on the eastern side, but as the Divide is approached more abrupt folding and even overturned folds, with some thrusting in places, can be discerned. West of the Divide severe earth-stresses have wrenched the whole mass and given rise to the marked over-thrusting and horizontal dislocation known as the Alpine Fault. (B.W.C.)

ORR, R. H.: *See* 58/44.

58/106—PANTIN, H. M.: Rate of Formation of a Diagenetic Calcareous Concretion. *J. sedim. Petrol. 28 (3)*: 366–71, 2 figs.

Age determinations by the C^{14} method were made on the matrix and enclosed fauna of a Quaternary calcareous concretion from the continental shelf south-east of Cape Campbell, New Zealand. It was formed within the last 19,500 years, and its formation probably occupied 7,500 years or less. The classification and terminology of concretions are also discussed. (From author's abstract.)

PEWE, T. L.: *See* 58/2.

58/107—REED, J. J.: Regional Metamorphism in South-east Nelson. *N.Z geol. Surv. Bull. n.s. 60,* 64 pp., 39 figs.

Regional metamorphism has been studied in an area about 50 miles long and 10 miles wide from Lake Rotoiti in the north to Lewis Pass in the south. Three metamorphic zones, based on the appearance of the index minerals, chlorite, biotite, and garnet, are recognised in quartzo-feldspathic rocks (greywackes and argillites). The chlorite zone is subdivided, on the degree of internal reconstitution, into three subzones, corresponding with three (of four) subzones – Chl. 1 to 3 – established by Hutton and Turner in the chlorite zone of Otago. The terminology of Hutton and Turner has been used for the Nelson subzones, but there are megascopic differences, notably the poorer development of schistosity.

The zones form a progressive metamorphic series in which the rank increases from east to west. In the west they are truncated by the Alpine Fault, whereas in the east the rocks of lowest rank (Chl. 1) apparently grade into unaltered greywackes and argillites. Chloritic schists are intercalated with the quartzo-feldspathic schists in the biotite and garnet zones, actinolite schists are known in Mill Stream in the biotite zone, and a quartz-stilpnomelane rock was found in the Chl. 3 subzone. Near the Alpine Fault, schists of the garnet and biotite zones have suffered retrograde metamorphism.

Field and laboratory data lead to the conclusion that the rocks of the schist belt are of upper Paleozoic to middle Triassic age. A single period of metamorphism is favoured, within the limits of post-middle Triassic and pre-uppermost Jurassic or lowest Cretaceous. Probably the metamorphism is coeval with the uppermost Jurassic(?) tectonic movements responsible for the folding of lower Mesozoic strata.

It is concluded that metamorphism took place at a depth greater than 50,000 ft, essentially by oriented crystal growth under a compressive stress normal to the schistosity planes (load metamorphism).

No payable mineralisation is known in south-east Nelson, in striking contrast with the gold-scheelite mineralisation in Otago and Marlborough. This may be related to the absence of the Chl. 4 subzone. (From author's abstract.)

58/108—REED, J. J.: Granites and Mineralization in New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 47–64, 2 figs.

Granite in New Zealand is confined to the South Island and Stewart Island. There are three major meridionally-trending belts in north-west Nelson – Separation Point to Mt Murchison, Kahurangi Point to Ahaura River, and Paparoa Range to Kongahu Point. Isolated granite masses are known in Westland and extensive areas in Fiordland and Stewart Island. The Separation Point to Mt Murchison granite differs from the others in being essentially a soda-alkali type.

Directly related to granite are copper-molybdenum-gold-silver-lead-zinc lodes at Mt Radiant and tungsten-tin lodes at Port Pegasus, Stewart Island; probably related are the Reefton gold lodes, many minor auriferous lodes, and a barite-fluorite deposit; possibly related are the gold-scheelite lodes in the Otago and Marlborough schists. Mining has now ceased except for scheelite, which is worked by small parties at Glenorchy.

Present knowledge of the age of the granites and mineralisation is summarised in a table. (Author's abstract.)

58/109—REED, J. J.: Additional Data on the Volcanic Argillites from Red Rock Point, Wellington. *N.Z. J. Geol. Geophys. 1 (4)*: 635–40, 4 figs.

The dove-grey volcanic argillite from Red Rock Point is petrographically and chemically very similar to the red and green volcanic argillites, and differs only in the degree of oxidation of the iron oxide. These volcanic argillites are considered to be mainly argillaceous in nature (at least 70 to 80%), with the admixture of volcanic material probably containing a high proportion of finely divided iron oxide. (Author's abstract.)

REED, J. J.: *See also* 58/6

58/110—REILLY, W. I.: Temperature Distribution about a Cooling Volcanic Intrusion. *N.Z. J. Geol. Geophys. 1 (2)*: 364–74, 5 figs.

The theoretical temperature distributions in the surrounding rocks following the injection of magma into a vertical dike and a vertical pipe are derived mathematically. It is concluded that the surface thermal gradient may remain abnormally high for a period of the order of thousands of years after the injection of the magma. (B.W.C.)

REILLY, W. I.: *See also* 58/114.

58/111—RICH, C. C.: Occurrence of Sterrasters of the Geodiidae (Demospongea, Choristida) in Late Cenozoic Strata of Western Wellington Province, New Zealand. *N.Z. J. Geol. Geophys. 1 (4)*: 641–6, 2 figs.

Sterrasters, the microsclere siliceous spicules of certain marine sponges, have been recognised in strata ranging in age from Kapitean (Upper Miocene) to Pleistocene, including some beds of the Pleistocene Hawera Series previously considered to be non-marine. The sterrasters are described and compared with those of modern and fossil sponges from New Zealand. The genus *Geodia* Lamarck is definitely represented. Sterrasters are useful indicators of marine deposition and may be widespread in the Upper Cretaceous and Cenozoic of New Zealand. (From author's abstract.)

58/112—RICHTER, C. F.: "Elementary Seismology". W. H. Freeman and Co., San Francisco. viii + 768 pp., ills.

Contains a chapter on New Zealand earthquakes. (Reviewed by K. E. Bullen in *Aust. J. Sci. 21 (7)*: 228 (1959).

58/113—ROBBINS, R. G.: Direct Effect of the 1855 Earthquake on the Vegetation of the Orongorongo Valley, Wellington. *Trans. roy. Soc. N.Z. 85 (2)*: 205–12, 1 pl., 7 figs.

The Wellington earthquake of 1855 was accompanied by elevation of as much as 9 ft and violently affected the Rimutaka Range, causing large slips on the western escarpment of the Orongorongo River valley. There is evidence that thousands of tons of greywacke rock caused catastrophic damage to forest vegetation. (From author's abstract.)

58/114—ROBERTSON, E. I.; REILLY, W. I.: Bouger Anomaly Map of New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 560–4, map.

The map shows two major negative gravity anomalies. The Rangitikei-Waiapu Anomaly, cutting across the axial ranges of the North Island at an angle, indicates an active crustal downwarp that is not in isostatic equilibrium. This anomaly is nearly parallel to the zone of intense seismic activity, the Taupo volcanic zone, and other geological features of the North Island. The Rimutaka-Ruahine axial ranges are apparently not underlain by mountain roots. On the other hand the Alpine Anomaly of the South Island is considered to be the gravitational expression of the crustal roots of the Southern Alps and its magnitude suggests that this region is in approximate isostatic equilibrium. (From authors' abstract.)

RONALDSON, J. W.: *See* 58/21.

58/115—SCAHILL, T. E. J.: Investigation of Some New Zealand Sands for Foundry Moulding. *N.Z. J. Sci. 1 (2)*: 342–60, 9 figs.

Physical and chemical properties of 28 samples of natural sands from both North and South Islands are described and discussed. Although none are ideal, several could be conditioned for foundry use. (B.W.C.)

58/116—SCHOFIELD, J. C.: Pliocene Shell Beds South of Manukau Harbour. *N.Z. J. Geol. Geophys. 1 (2)*: 247–55, 2 figs.

Shell beds exposed at the surface and others drilled at depths down to 200 ft below sea-level are of the same age and facies as the Otahuhu shell bed and are assigned to the Kaawa Formation (probably Opoitian). There is no evidence for deformation of these Pliocene sediments. (Author's abstract extended.)

58/117—SCHOFIELD, J. C.: Geology of Motuihe Island, Waitemata Harbour. *N.Z. J. Geol. Geophys. 1 (3)*: 485–9, 1 fig.

Waitemata Formation strata, probably of Otaian age, unconformably overlie a highly irregular, unweathered surface cut in rocks of Mesozoic age. A tuffaceous sandstone within the former is correlated with the Parnell Grit horizon. It contains large blocks of Waitemata sandstone and mudstone.

The majority of dips are considered to be the result of compaction rather than tectonic movement.

The ground-water reservoir consists of an irregularly shaped fresh-water lens resting on salt water. A few drillholes that originally supplied fresh water have become salty. Others may do so unless pump intakes are kept at or above mean sea level. (Author's abstract.)

58/118—SCHOFIELD, J. C.: Notes on Volcanism and Structure in Franklin County. *N.Z. J. Geol. Goephys. 1 (3)*: 541–59, 8 figs.

The basaltic rocks of Franklin County, South Auckland, are divided into two formations, the Franklin Basalts and the Bombay Basalts. The age of the former is Mid-Pleistocene, younger than the Tyrrhenian sea level of 110 ft, and older than the Monasterian sea levels of 40 to 80 ft; the latter may be Late Pliocene to Early Pleistocene in age.

Faulting of Pleistocene age has been due mainly to collapse along pre-existing fractures, following expulsion of lava. Nevertheless, transcurrent faulting shows that some horizontal compression was present. The local principal horizontal stress direction is likely to have been north-north-east during and since the Miocene, but the main period of faulting ceased prior to volcanism. (Author's abstract.)

58/119—SCOTT, G. H.: Distribution of Populations of Fossil Foraminifera. *N.Z. J. Geol. Geophys. 1 (3)*: 474–84, 4 figs.

An experiment was conducted to investigate the nature of the distribution of individual members of a faunule within one lithologic unit. The samples studied were taken from the section exposed at Bluecliffs, South Canterbury (type Otaian). It was found that while for some species samples were drawn from common populations, there were other groups for which sampling indicated heterogeneity. It is concluded that the practice of taking single samples from beds or from wide stratigraphic intervals in uniform lithologies does not justify generalisations covering the whole of the sampling interval. (Author's abstract modified.)

58/120—SEARLE, E. J.: A Note on the Formation of Native Iron and Other Effects Associated with Contact of Basalt and Carbonized Wood at Auckland, New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 451–8, 5 figs.

The basalt surrounding a tree mould in a flow from Mt Wellington, Auckland, has been found to contain native iron produced by reduction of ore. Shrinkage cracks in the charcoal within the mould have been invaded by an alkali-rich residium of the basalt, thus providing a small-scale example of "filter-press" differentiation. (Author's abstract.)

58/121—SEARLE, E. J.: Pleistocene and Recent Studies of Waitemata Harbour. Part 1 – The Main Channel. *N.Z. J. Geol. Geophys. 1 (3)*: 501–8, 4 figs.

Some features of the bed of Waitemata Harbour are described and four cross profiles of the main stream are presented. The profiles afford evidence of an interval of stillstand during the Last Glaciation or earlier at an elevation approximately 30 feet below modern sea level. (Author's abstract.)

58/122—SKWARKO, S. K.: The Lower Ordovician of Cape Providence: A New Graptolite Zone and a New Species of *Schizograptus. N.Z J. Geol Geophys. 1 (2)*: 256–62, 2 figs.

New graptolite collections from Cape Providence, Fiordland, north of the section described by Benson and Keble in 1935, show a repetition, in reverse order, of the beds known to the south, together with the Upper Lancefieldian Zone, not previously recognised in New Zealand. This zone is represented by three species of *Tetragraptus* and *Schizograptus waddickorum* n. sp (related to the Lower Bendigonian *S. spectabilis* of Victoria). (From author's abstract.)

SMITH, B. A. J.: *See* 58/32.

58/123—SMITH, J. H.: Production and Utilisation of Geothermal Steam. *N.Z. Engng. 13 (10)*: 354–75, 13 figs.

This paper deals mainly with the exploration of the Wairakei steam field and plans for the generation of 250 MW of electricity. Details of some 24 exploration wells and 33 production wells drilled up to the end of 1957 are given, and the geology of the area described. Other sections deal with drilling methods, the testing of bore output, and the problems of mineral deposition and corrosion. See also discussion, *ibid. 14 (5)*: 159–60 (1959). (B.W.C.)

58/124—SPEDEN, I. G.: A Note on the Age of the Jurassic Flora of Owaka Creek, South-east Otago, New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 530–2, 2 figs.

The Owaka Creek flora, attributed to the Rhaetian or Lower Jurassic by Arber in 1917, is from beds that overlie Lower to Middle Callovian marine sediments, dated by ammonites, and is thus younger than previously thought. (Author's abstract.).

58/125—SPEDEN, I. G.; MCKELLAR, I. C.: The Occurrence of Aratauran Beds South of Nugget Point, South Otago, New Zealand. *N.Z J. Geol Geophys. 1 (4)*: 647–52, 3 figs.

The upper part of the Otapirian Stage and the Aratauran Stage are recognised in the sequence south of Nugget Point, and the position of the Triassic-Jurassic boundary fixed. (From authors' abstract.)

58/126—SQUIRES, D. F.: The Cretaceous and Tertiary Corals of New Zealand. *N.Z. Geol. Surv. paleont. Bull. 29.* 107 pp., 16 pls., 28 figs.

No major systematic study of New Zealand fossil corals had been made since J. E. Tenison-Woods described 27 species from the Tertiary in 1880. As a result of the current work, 64 species and subspecies belonging to 47 genera and subgenera have been recognised. Of these, 22 species and 2 genera are new. Corals are reported from the Cretaceous of New Zealand for the first time. The origins and relationships of the coral fauna are discussed, and the stratigraphic and geographic distribution and paleoecology described. All 64 species and subspecies are systematically described and figured. (B.W.C.)

58/127—STEINER, A.: Petrogenetic Implications of the 1954 Ngauruhoe Lava and its Xenoliths. *N.Z. J. Geol. Geophys. 1 (2)*: 325–63, 21 figs.

The Ngauruhoe lava erupted in 1954 is an olivine-bearing basic andesite, and belongs to the Taupo volcanic association of basalts, basaltic andesites, pyroxene andesites, dacites, rhyolites, and ignimbrites. A characteristic feature of the lava is the abundance of small quartzose and feldspathic xenoliths, and intensely vitrified gneissic xenoliths of boulder size. Structural, petrographic and chemical data indicate that all the xenoliths are derived from acid gneiss. Similarity in chemical composition between the vitrified xenoliths and the rhyolites and ignimbrites suggests that the acid effusive rocks of the Taupo association originated from an acid magma produced by transfusion of acid gneiss in prolonged contact with olivine basalt magma at great depth. (From author's abstract.)

58/128—STEINER, A.: Occurrence of Wairakite at The Geysers, California. *Amer. Mineral. 43 (7–8)*: 481.

Wairakite, first discovered in hydrothermally altered rocks in New Zealand, has been identified in a greywacke fragment erupted from a well drilled at The Geysers. The mineral replaces feldspar and its occurrence resembles that at Wairakei. (B.W.C.)

58/129—STEVENS, G. R.: The Wellington Fault *Trans roy. Soc. N.Z. 85 (4)*: 633–46, 4 pls., 3 figs.

The Wellington fault is not a single plane of movement but a wide crush zone which passes laterally into a complex zone of anastomosing faults and then into a more open system of minor faults. The fault, which is active and markedly transcurrent, has a long history of movement. Since the beginning of the Pleistocene it has probably dislocated Trias-Jura greywackes some 2,000 feet.

Fault movements within the uniform greywackes have been charted by the use as a datum of an ancient erosional surface recognised by geomorphic studies. It has also been possible to study the distribution and map the pattern of ancient faults. Minor as well as major faults of the Wellington Fault System are commonly marked by zones of intense crushing, and these zones are deeply etched by erosion. (From author's abstract.)

58/130—STUDT, F. E.: Geophysical Reconnaissance at Kawerau, New Zealand. *N.Z. J. Geol. Geophys. 1 (2)*: 219–46, 10 figs.

Geophysical methods were used to investigate the possibility of exploiting the Onepu hydrothermal resources in the Kawerau paper mills. Changes in the hydrology and chemistry of the hot springs in the last fifty years are attributed to downcutting by the Tarawera River. Electrical surveying extended the known hot-water zone across the Tarawera River, where test holes gave satisfactory steam and water discharges, and exploitation followed. Seismic refraction tests showed the existence of extensive rhyolites, which, being less permeable than the pumice sediments, act as cap rocks in the hydrothermal system. These rhyolites have little influence on the magnetic field intensity, having low remanent polarisation. A gravity survey reveals some details of the geological structure and suggests a genetic relationship between the hot water and rhyolitic intrusions, and between faulting and the volcanic cone of Mt Edgecumbe. (From author's abstract.)

58/131—STUDT, F. E.: The Wairakei Hydrothermal Field under Exploitation. *N.Z. J. Geol. Geophys. 1 (4)*: 703–23, 8 figs.

Heat flow through drillholes in the Wairakei hydrothermal field now equals the pre-existing natural heat escape, while this heat escape itself is little diminished. The total heat flow at the surface has thus been doubled, and the source of this increase has an important bearing on the life of the field under exploitation.

The drillholes tap the Waiora aquifer, in which the low density of the hot water gives rise to pseudo-artesian pressure, here designated thermo-artesian. There has been a general decline in this pressure, and consequently cold water must be encroaching on the field, although drillhole temperatures show little evidence of this. Some of the increased heat flow must therefore come from heat stored in the rocks and ground water, and this is a wasting asset. (From author's abstract.)

58/132—SUGGATE, R. P.: Late Quaternary Deposits of the Christchurch Metropolitan Area. *N.Z. J. Geol. Geophys. 1 (1)*: 103–22, 8 figs.

Deep wells sunk for artesian water beneath Christchurch penetrate three formations. The youngest, the Christchurch Formation, consists of marine, estuarine, and fluviatile deposits of which at least the upper part was formed during the postglacial rise of sea level. It extends down to more than 200 ft below present sea level, and radiocarbon dates record part of the rise of sea level, from — 73 ft 9,400 years ago to — 12 ft 6,100 years ago. Other dates, together with topographic and soil evidence, are interpreted as indicating the subsequent period of development by the Waimakariri River of a fan of gravel over the Christchurch area, probably completed about 2,000 years ago when sea-level was a little higher than at present. The aggradation surface of this fan is termed the Yaldhurst Surface.

The Riccarton Gravel, on whose eroded surface the Christchurch Formation lies, is thought to be the sub-surface representative of the gravel that forms an earlier fan, whose surface – the Halkett Surface – also has characteristic soils. This fan is believed to have developed as the result of aggradation by outwash streams during the last but one major advance of "Last" Glaciation age.

Glacial outwash gravels of a still earlier "Last" Glaciation advance form an older fan whose surface – the Darfield Surface – is also recognised from topographic and soil evidence. No sub-surface representative of these gravels is recognised beneath Christchurch.

The Bromley Formation, estuarine and marine gravel, sand, silt, and peat, extends down to several hundred feet below the Riccarton Gravel beneath most of Christchurch; it is thought to be of "Last" Interglacial age. In the western part of the Christchurch area, thick gravel beneath the Riccarton Gravel may perhaps be of "Penultimate" Glaciation age. (Author's abstract.)

58/133—SUGGATE, R. P.: The Geology of the Clarence Valley from Gore Stream to Bluff Hill. *Trans. roy. Soc. N.Z. 85 (3)*: 397–408, 3 figs.

Cretaceous rocks, Motuan (Turonian) to Haumurian (Maestrichtian) in age, rest with major unconformity on indurated sandstone and mudstone, known to be at one place Jurassic (Heterian?).

The Split Rock Formation (Motuan – ? Ngaterian) is mainly sandstone and mudstone lithologically similar to Clarence Series sandstone and mudstone at Coverham. The Gridiron Formation (Ngaterian), resting unconformably on the Split Rock Formation or on Jurassic rocks, is mainly fresh-water or marine sandstone interbedded with volcanic rocks, and is different from either the Clarence or Raukumara Series rocks of Coverham. The Seymour Formation (Arowhanan-Haumurian), conformable on the Gridiron Formation, is marine sandstone overlain by sulphureous siltstone and sandstone that are similar to Haumurian beds at Coverham. The Cretaceous sequence as a whole is transitional in character between the lower Clarence valley and North Canterbury sequences.

The Tertiary marine formations, unconformable on the Cretaceous, are briefly discussed. (Author's abstract.)

SUGGATE, R. P.: *See also* 58/54, 58/55, and 58/97.

58/134—SUGGATE, R. P., and WILSON, D. D.: Geology of the Harper and Avoca River Valleys, Mid-Canterbury, New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 31–46, 4 figs.

Soft Tertiary sandstone, mudstone, and conglomerate are preserved in a narrow strip parallel to the Harper Fault, within indurated sandstone and mudstone probably Triassic in age on the east flank of the Southern Alps. The structure of the Tertiary rocks is interpreted principally in terms of mid-Tertiary and late-Tertiary folding, to which some of the complexities of the basement structure are also attributed. Valley deposits and valley form are interpreted as the result of two ice advances during the Last Glaciation. (Authors' abstract.)

SWINDALE, L. D.: *See* 58/9.

58/135—TE PUNGA, M. T.: Evidence for a Low Sea-Level 9900 Years Ago. *N.Z. J. Geol. Geophys. 1 (1)*: 92–4.

Radiocarbon dating of *Podocarpus* wood from a well at Foxton suggests that sea level may have risen about 150 ft during the last 9,900 years, but there is no decisive evidence to indicate whether the land at the well site has been stable or tectonically elevated or depressed in recent times. (Author's abstract.)

58/136—THOMPSON, B. N.: The Geology of the Atiamuri Dam Site. *N.Z. J. Geol. Geophys. 1 (2)*: 275–306, 10 figs.

The Atiamuri hydro-electric power station is founded on the summit of a dome of vertically banded Patetere Rhyolite buried beneath rhyolitic pumice breccias and fluviatile sands and gravels. Hydrothermal solutions silicified part of the rhyolite and altered and silicified portions of the pumice breccias near the dam site. Of three prominent terrace systems the highest is correlated with the Hinuera terrace at Karapiro, and the second results from aggradation due to pumice eruptions in the Taupo area about 130 A.D. Dam and power-house sites were selected after suitable foundations had been proved in a narrow section of the river valley that was free from major leakage channels. (From author's abstract.)

WASHBURN, A. L.: *See* 58/56.

58/137—WATERHOUSE, J. B.: The Occurrence of *Atomodesma* Beyrich in New Zealand. *N.Z. J. Geol. Geophys. 1 (1)*: 166–77, 2 figs.

The lamellibranch genus *Maitaia* Marwick 1934, widespread in the upper Paleozoic deposits of New Zealand is a synonym of the Timor genus *Atomodesma* Beyrich, 1864. A new species of probable Artinskian age (*A. marwicki*) is described, and the description of *A. trechmanni* (Marwick) (probably Kungurian) emended. (Author's abstract extended.)

58/138—WATERHOUSE, J. B.: The Age of the Takitimu Group of Western Southland. *N.Z. J. Geol. Geophys. 1 (4)*: 604–10.

A marine fauna from low in the Takitimu Group is discussed and considered to be probably Sakmarian (Lower Permian) from its affinities to faunas from New South Wales and Queensland. The Takitimu Group is probably Sakmarian and lower Artinskian rather than Carboniferous in age. (Author's abstract modified.)

58/139—WATTERS, W. A.: Some Zoned Skarns from Granite-Marble Contacts near Puyvalador, in the Quérigut Area, Eastern Pyrenees, and Their Petrogenesis. *Mineral. Mag. 31 (240)*: 703–25, 1 pl., 6 figs.

Descriptions, with chemical and mineralogical data, are given of zoned wollastonite-grossular-clinozoisite skarns from near Quérigut, France. The features of the granite-limestone contacts are compared and contrasted with those described from other regions. (From author's abstract.)

58/140—WEBBY, B. D.: A Lower Mesozoic Annelid from Rock Point, Southwestern Wellington, New Zealand. *N.Z. J. Geol. Geophys. 1 (3)*: 509–13, 5 figs.

Titahia corrugata, a new genus and species of agglutinating annelid (Terebellidae), is described from the greywacke-argillite rocks near Titahi Bay. (Author's abstract.)

WILLETT, R. W.: *See* 58/6.

WILLIS, E. H.: *See* 58/55.

WILSON, D. D.: *See* 58/134.

58/141—WOOD, B. L.: Submarine Geology of Bluff Harbour. *N.Z. J. Geol. Geophys. 1 (3)*: 461–9, 4 figs.

In a small area at the southern end of Bluff Harbour, which has been explored by submarine drilling, a thin sequence of moderately compacted late Tertiary terrestrial and estuarine beds rests on a basement of Paleozoic intrusive and metamorphic rocks, and is overlain by uncompacted Recent estuarine sands. The basement rocks are decomposed to a depth of 45 ft beneath the Tertiary beds which also have undergone a similar type of decomposition with leaching. The Tertiary beds are of Taranaki or lower Wanganui age (Upper Miocene to Pliocene). (Author's abstract.)

WOOD, B. L.: *See also* 58/66.

WOOD, E. J. F.: *See* 58/35.

WOOLLARD, G. P.: *See* 58/1.

58/142—YALDWYN, J. C.: Notes on the Environment and Age of the Sub-Fossil Deposits of the Martinborough Caves. *Rec. Dom. Mus.* [*Wellington, N.Z.*] *3 (2)*: 129–33.

An age of less than 11,000 years is suggested for the cave deposits in the Ruakokopatuna Valley, as they are clearly younger than a layer of solifluxion debris which was emplaced during a periglacial episode that may be considered as contemporaneous with the "Mankato Glaciation". A mixed podocarp-broadleaf forest was formerly present in the area of the caves. The sub-fossil insect, molluscan, and reptile fauna is consistent with forest conditions during deposition. (Author's abstract.)

ZUMBERGE, J. H.: *See* 58/3.

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